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THE USE AND MISUSE OF MULTIPLE REGRESSION IN IDENTIFYING IMPORTANT PROCESS VARIABLES

by

G. J. Hahn and S. S. Shapiro

Report No. 66-C-178

May 1966

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THE JOINT ASSESSMENT OF NORMALITY OF SEVERAL INDEPENDENT SAMPLES

by

S. S. Shapiro and M. B. Wilk*
Information Sciences Laboratory

Report No. 67-C-322

August 1967

*Bell Telephone Laboratories, Inc.

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TECHNICAL INFORMATION SERIES

AUTHORS	SUBJECT	NO.
C.E. Pangburn C. Arabadjis	Statistics	R67SIPD12
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TITLE		GE CLASS 1
The Log-Normal Distribution		GOVT. CLASS. Unclassified
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SUMMARY

This report provides engineers and technicians with tools by which they can determine whether data is log-normally distributed, and if it is so distributed, provides a means by which they can best find the estimator of the mean and variance of the distribution. In providing these tools, the log-normal distribution was first analyzed and such expressions as those for moments and cumulative probabilities were derived. Estimation techniques are discussed, and a comparison of errors is graphically presented.

Four time-sharing BASIC programs have been written, and these are discussed fully. The programs are used to: describe log-normal distributions, estimate the mean and variance of log-normally distributed data, and test data for log-normality, using a chi-squared goodness-of-fit test.

KEY WORDS Estimation, time sharing, probability density function, confidence limits, reliability, mean-squared error.

INFORMATION PREPARED FOR _____

TESTS MADE BY _____

AUTHORS C.E. Pangburn and C. Arabadjis

COMPONENT Systems Development Engineering

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by

C. D. DOYLE

SCHENECTADY, NEW YORK

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by

W. G. Morrison, Jr.

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J.J. Fleck, Information Sciences Laboratory

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Schenectady, N.Y.

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W. B. Nelson
Information Science & Engineering

Report No. 71-C-042

January 1971

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ENGINEERING AND STATISTICAL PROBLEMS ASSOCIATED WITH THE INSPECTION OF MOLDS

by

George J. Hurwitz

Army Chemical Center

In the past the members of the Baltimore Section have been treated to talks by personnel from the Quality Assurance Division, Chemical Corps Materiel Command on the need for coordination between the statistician and the engineer and the benefits which can result from such a coordinated effort. The problem to be discussed aptly illustrates this team work which resulted in a substantial dollar and manpower saving, and the resolution of a difficult although very interesting problem. All of the statistics shown were prepared by Quality Assurance Division statisticians and will illustrate the F Test, "t" Test, Analysis of Variance and Wilcoxon Ranking Method.

The problem involved the dimensional inspection of vacuum forming molds used in the fabrication of a certain type of gas mask. A vacuum forming mold is a metallic device shaped in the form that will cure the rubber into the shape it will ultimately assume. Chemical Corps specifications require that the molds used by the fabricator be approved by the Chemical Corps prior to use. In addition, since the molds become Government property at termination of the contract, inspection is also required prior to placing in storage for subsequent use on another contract.

The usual procedure is to mount the mold on a flat plate, rule off lines 1/2" apart in both the horizontal and vertical directions and then determine the distance of the intersections from the base line. By this procedure approximately 500 individual points on the mold are determined and compared with the drawing. Set up time was approximately 7 hours and an equal time was required to make the measurements. Total cost in labor to inspect one mold was $42.00. Although the cost of the mold is not a factor since the mold can be used to produce a large quantity of masks, it is interesting to note that the cost of initial inspection was 21% of the cost of the mold. Since another inspection would be required at the end of the contract, it can be seen that the cost of mold inspection could become a sizeable sum, particularly as in this case about fifty molds were involved. The problem therefore was to determine what savings could be accomplished in inspection cost and still have sufficient information upon which to base a decision with respect to the following:

INTRODUCTION TO WORK SAMPLING

Stanley R. Kalin
Chief Industrial Engineer

The National Plastics Products Company
Odenton, Maryland

The p, or percent defective chart is a device well known in the quality field for its ability to provide an estimate of percent defective in a run. It owes its utility to the basic statistical truth that a sample taken in a random manner from a universe will tend to reflect the characteristics of that universe. Ordinarily the characteristics are length, diameter, tensile strength or other quality features. But if we were to consider a universe consisting of all the minutes in the day of a production machine at random minutes and noting if it were productive or idle, we should then be able to estimate how the day was divided into productive and idle time.

The eminent British Statistician L. H. C. Tippett first used this technique, which was later to become known as Ratio Delay Study, when he applied statistical sampling to the problem of predicting loom breakdown in a textile mill in England. (1) The first appearance in this country was in 1940. (2) The term "work sampling" is currently used to describe an expanded concept in which the technique is used to gather facts not only about machines but about men as well. (3)

As an example of how Work Sampling might apply to an actual case, let us assume Department X of our plant has submitted a request for an additional bench grinder on the ground that the one in the department cannot keep up with the amount of grinding to be done. To check this allegation we might elect to use work sampling techniques, in which case we would proceed as follows: Mark a piece of paper <u>productive</u> and <u>idle</u>, in two columns, and wander through department X at random intervals observing the grinder. If the grinder is operating when observed, place a tally mark in the <u>Productive</u> column, and if idle, place a tally mark in the <u>Idle</u> column. Do this at random throughout the day, and repeat until somewhere between 500 and 3000 observations are recorded. Take the number of tallies in the Idle column and divide by the total number of observations made. This fraction times 480, the number of minutes in an 8 hour working shift, gives the total minutes the grinder is idle per day on the average. If the amount of idle time is sufficient to care of the excess work load complained of, the new machine is probably not justified.

Work Sampling is based on the binomial distribution. Confidence limits are easily computed by means of the following:

$$\sigma = \sqrt{\frac{p\,q}{n}}$$

Transactions Paper

(Reviewed and Accepted for Publication)

Thesis

FACTORS AFFECTING THE LIGHTNING PERFORMANCE OF TRANSMISSION LINES

J. H. Hagenguth
Fellow AIEE

J. G. Anderson
Member AIEE

Both of:
General Electric Co.
Pittsfield, Mass.

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Fall General Meeting, Chicago, Ill., October 7-11, 1957. Manuscript submitted May 31, 1957; made available for printing August 20, 1957.

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Theory

S. B. Griscom
Fellow AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

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Theory

THE LIGHTNING STROKE

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ARC DROP DURING TRANSITION FROM SPARK DISCHARGE TO ARC

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Charles J. Miller, Jr.
Fellow AIEE
The Ohio Brass Company
Barberton, Ohio

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To be presented at the AIEE Middle Eastern District Meeting,
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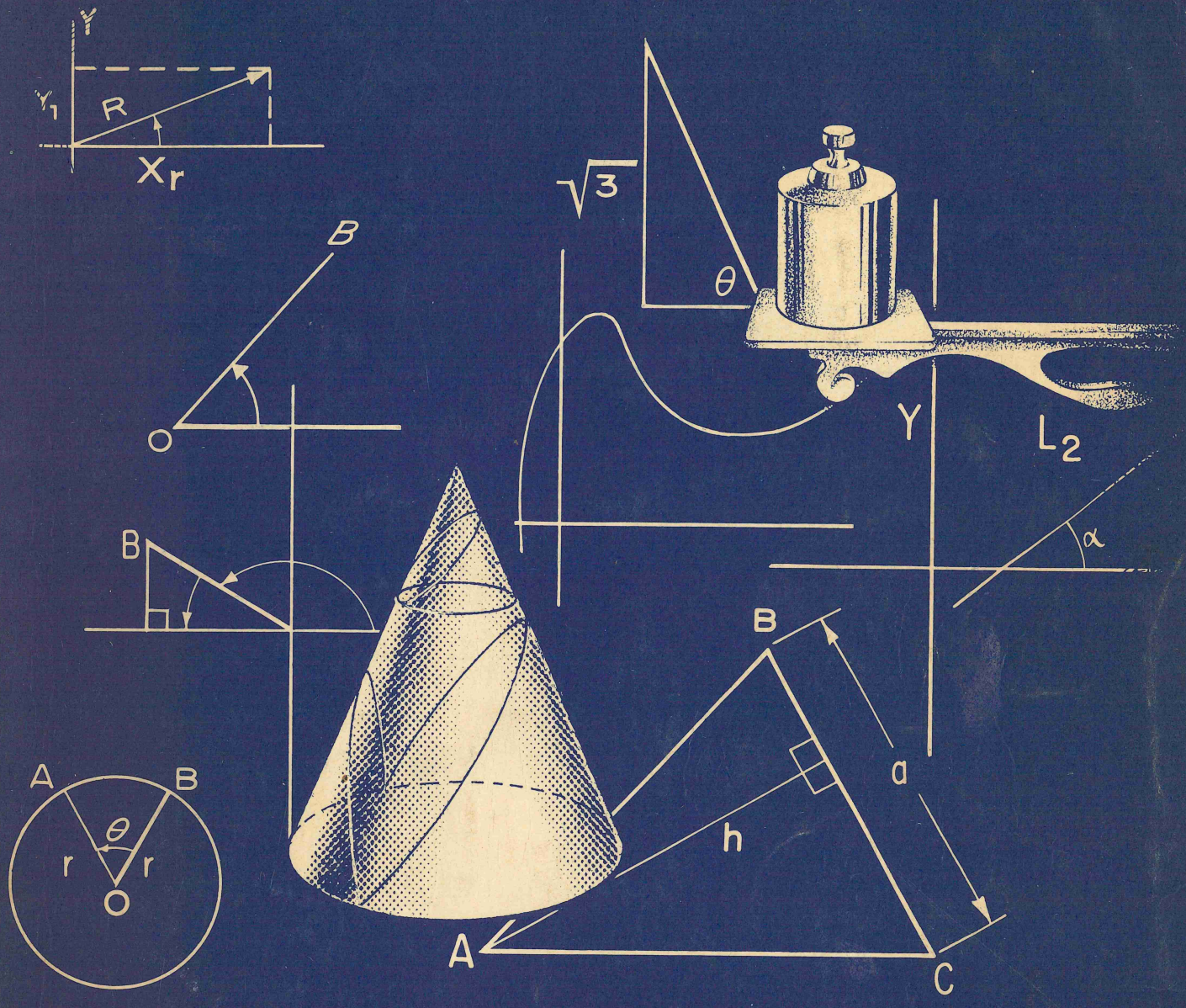

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by

J.D. Cobine

SCHENECTADY, NEW YORK

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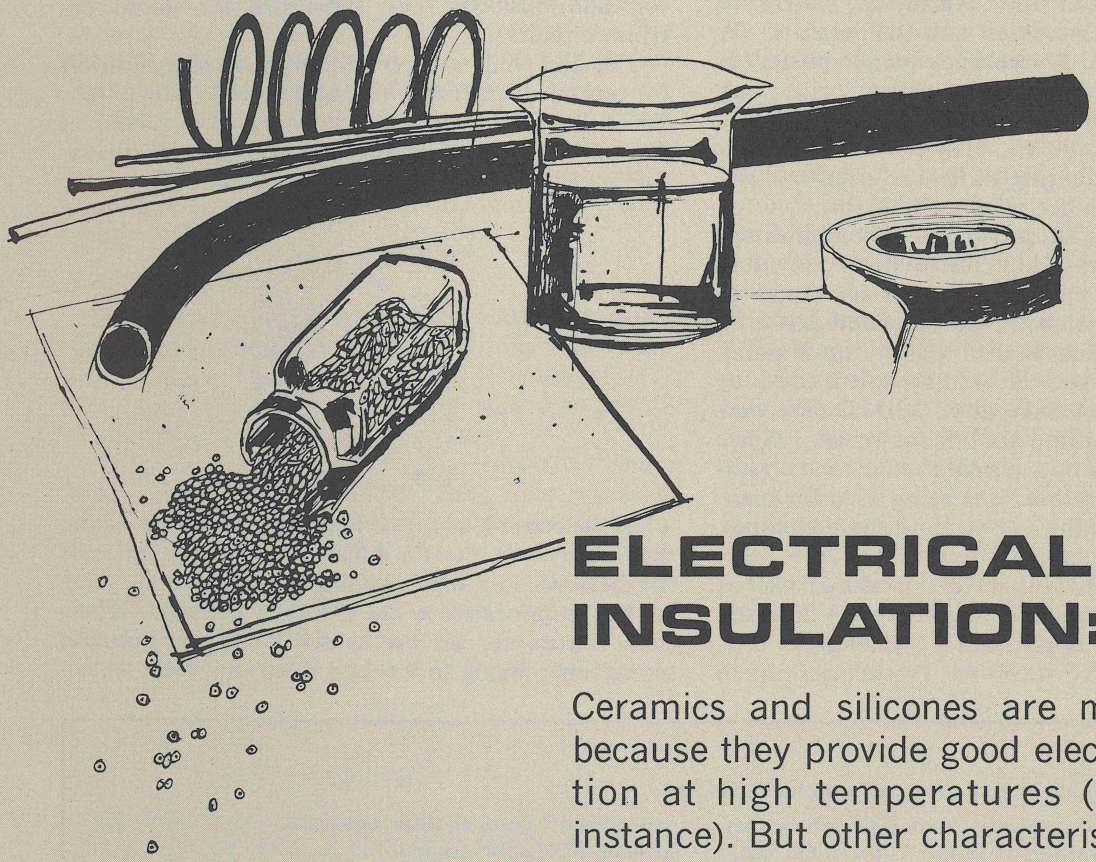

ELECTRICAL INSULATION: 1966

Ceramics and silicones are making news because they provide good electrical insulation at high temperatures (700° C, for instance). But other characteristics—formability, weight, moisture resistance—make epoxy resins and polyurethane foams equally important. New techniques, such as transfer molding, permit substantial cost reductions in semiconductor components. Here are some of the latest advances in insulation materials and forming processes—with data for comparing them.

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Mr. Kaminski
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SURFACES, STRESS-DEPENDENT REACTIONS, AND STRENGTH

by

W. B. Hillig and R. J. Charles

Report No. 64-RL-3756 M

October 1964

CLASS 1

SCHENECTADY, NEW YORK

Journal of Research of the National Bureau of Standards Vol. 57, No. 3, September 1956 Research Paper 2704

A High-Voltage Pulse Generator and Tests on an Improved Deflecting System of a Cold-Cathode Oscillograph

Harold N. Cones

An improved deflecting system for a cold-cathode oscillograph is described. This deflecting system reduces transit-time errors and eliminates errors due to impedance mismatch between the signal coaxial cable and the deflector.

A high-voltage pulse generator for producing single pulses in the millimicrosecond range was devised, and its use in testing the improved deflecting system is explained.

1. Introduction

The cathode-ray oscillograph (CRO) is an indispensable tool in high-voltage surge testing and research. However, the requirements of an oscillograph for his work are somewhat different from the requirements of the usual laboratory oscillograph. Sensitivity is not an important factor, as ample signal voltage is available. In fact, the available voltage is usually limited only by the flashover voltage of the fittings on the coaxial cable between the source of voltage to be measured and the oscillograph.

High writing speed is essential, as it is necessary to record on film single transients of a few millimicroseconds duration. This high writing speed is attained by the use of high accelerating voltages for the electron beam, and in many cases by allowing the beam to impinge directly on the photographic emulsion instead of photographing a trace on a fluorescent screen.

Cold-cathode oscillographs of the type described by Ackermann [1][1] are used in the Bureau's high-voltage laboratory and are entirely adequate for ordinary surge work.

However, with increasing interest in studies of steep-front voltage surges, the ability to faithfully record single transients of approximately 50-mμsec duration is essential. A resolution of time intervals of the order of 1 mμsec for the current and voltage records is highly desirable in making a detailed study of the mechanism of spark breakdown.

To record such rapid transient variations, a very high writing speed is necessary. Also, recording errors in the oscillograph, as well as those arising from its connections, which are not significant at lower recording speeds, become important and must be reduced or eliminated. Actually, a sufficiently high writing speed was insured by using Park's method of beam intensification [2]. Therefore, the recording errors introduced by the oscillograph itself and the means adopted for their elimination form the basis of the present study.

[1] Figures in brackets indicate the literature references at the end of this paper.

2. Cathode-Ray Oscillograph Recording Errors

Two sources of error of the CRO are of concern when very short transients are to be recorded. One is the error due to the transit time of the electrons in passing from one end to the other of the deflecting plates. The other error is caused by impedance mismatch in connecting the deflecting-plate circuit to a coaxial cable.

A typical cold-cathode oscillograph uses an accelerating voltage of 50 kv and has deflecting plates 3 cm long. The velocity of 50-kv electrons is 1.23×10^{10} cm/sec, and the corresponding transit time is 2.44×10^{-10} sec. The error arising from transit time will be 5 percent at 600 Mc for a pure sine wave.[2] For a steeply rising pulse the error will be 5 percent for a pulse with a rise time of 2.4 mμsec.[3] Although, in general, for steep-front surge work, errors due to transit time can be neglected, pulses with rise times of this order occur and are important in studies of spark breakdown.

The errors arising from impedance mismatch are more serious. The capacitance of the deflecting plates in the typical cold-cathode oscillograph is about 15×10^{-12} f, and the associated lead inductance is about 2 or 3×10^{-8} h, giving rise to a resonance frequency of 200 to 300 Mc. Hence, for all but somewhat lower frequencies, disturbing reflections will occur, giving rise to a voltage at the deflecting plates that may be quite different from the voltage at the input end of the cable. Furthermore, steeply rising pulses will force the deflecting-plate system into oscillation. The modification of an oscillograph to reduce these errors and the testing of the modified oscillograph are now described.

3. Redesign of Deflecting Plate System

One method of reducing the above errors is to drastically reduce the size of the deflecting plates. The transit time can in this way be reduced by the

[2] See the appendix, which is a discussion by J. H. Park of transit-time errors. This discussion is an excerpt from an unpublished informal communication.

[3] These values do not take into account the effect of fringing field at the ends of the plates. This increases the effective length of the plates and increases the error due to transit time.

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SPARKOVER CHARACTERISTICS OF LARGE GAP SPACES

AND LONG INSULATION STRINGS

T. Udo
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Tokyo, Japan

A paper recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Summer General Meeting and Nuclear Radiation Effects Conference, Toronto, Ont., Canada, June 16-21, 1963. Manuscript submitted March 15, 1963; made available for printing May 23, 1963.

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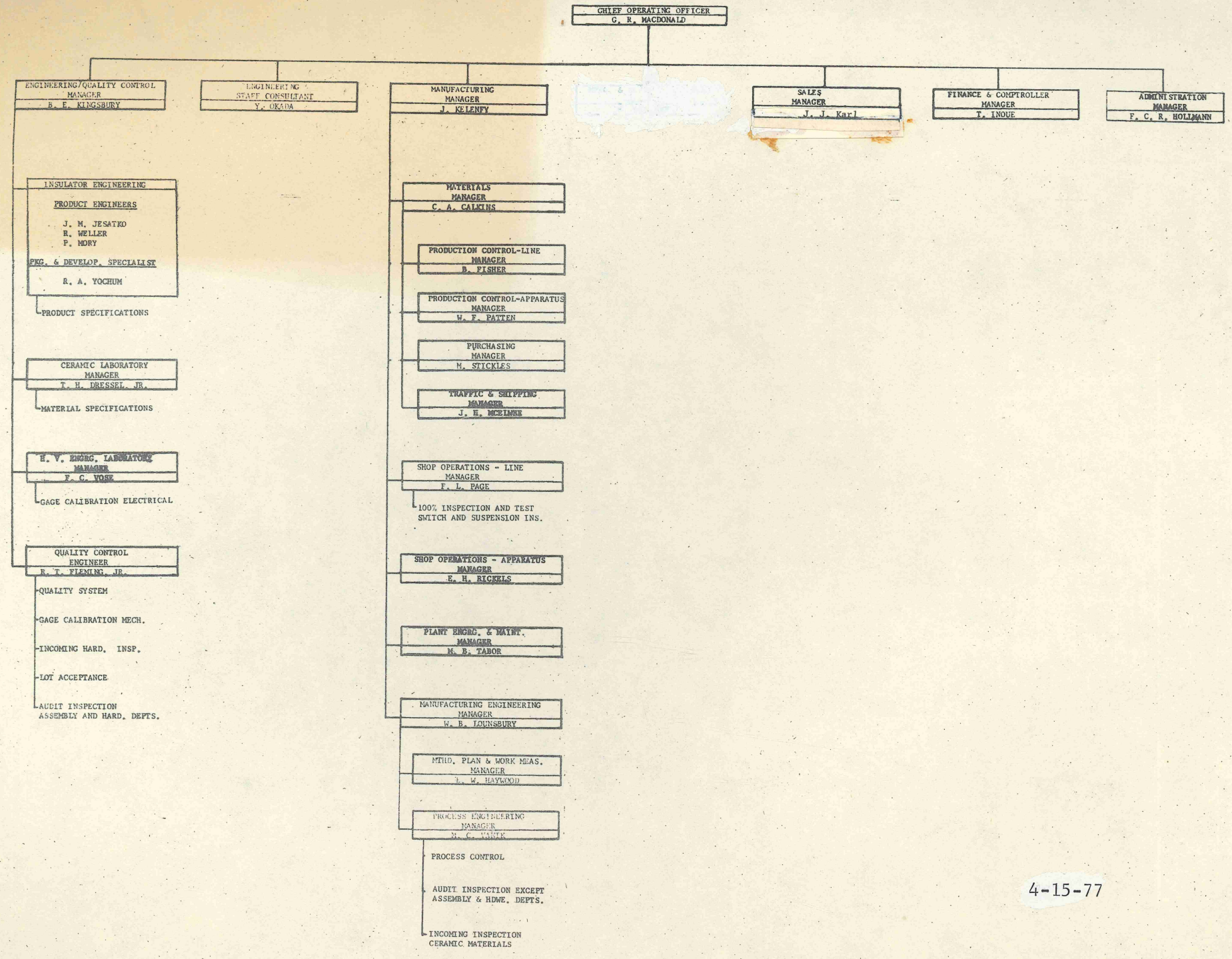
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4-15-77

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Transactions Paper

(Reviewed and Accepted for Publication)

THE INFLUENCE OF WATER RESISTIVITY AND PRECIPITATION RATE UPON SIXTY-CYCLE WET FLASHOVER VOLTAGE

AIEE Working Group on Rain Tests
of the
AIEE Subcommittee on Techniques for Dielectric Tests

A paper recommended by the AIEE Special Instruments and Auxiliary Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., February 2-7, 1958. Manuscript submitted October 15, 1957; made available for printing October 31, 1957.

For personnel of AIEE Working Group on Rain Tests, see page 1 of text.

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NEMA No. 140-1952

ASA
Reg. U. S. Pat. Off.
C29.2-1955
UDC 621.315.624

American Standard

Wet-Process Porcelain Insulators

(Suspension Type)

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Approved August 5, 1955

AMERICAN STANDARDS ASSOCIATION
INCORPORATED

ASA
C76.1 - 1943

AIEE
No. 21
June 1942

American Standards

for

APPARATUS BUSHINGS

AND

TEST CODE FOR APPARATUS BUSHINGS

APPROVED

American Standards Association

July 23, 1943

SPONSOR

Electrical Standards Committee

Published by
THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West Thirty-ninth Street, New York

ASA
C68.1
1953
UDC 621.317.32

AIEE
No. 4

American Standard

for

MEASUREMENT of VOLTAGE in DIELECTRIC TESTS

Approved as American Standard by the
American Standards Association
September 11, 1953

SPONSOR
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Published by
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33 West Thirty-ninth Street, New York 18, N. Y.

ASA
Reg. U. S. Pat. Off.
C63.4-1963

UDC 621.396.822:621.317.32

American Standard Methods of Measurement of

Radio-Noise Voltage and Radio-Noise Field Strength

0.015 to 25 Megacycles/Second Low-Voltage Electric Equipment and Nonelectric Equipment

USA Standard

This USA Standard is one of nearly 3000 standards approved as American Standards by the American Standards Association. On August 24, 1966, the ASA was reconstituted as the United States of America Standards Institute. Standards approved as American Standards are now designated USA Standards. There is no change in their index identification or technical content.

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Mechanics

GENERAL ELECTRIC

Research Laboratory

SURFACE EFFECTS IN FLOW AND FRACTURE

by

A. N. Holden

Report No. RL-411 August 1950

SCHENECTADY, NEW YORK

DESIGN DATA

DESIGN OF APPARATUS TO WITHSTAND
SHORT-CIRCUIT FORCES

July 20, 1953

GENERAL ELECTRIC STANDARDS

PRINTED IN U.S.A.

*Supersedes issue of January 1, 1944

Transactions Paper

(Reviewed and Accepted for Publication)

Mechanics

RESULTS OF HIGH-CURRENT TESTS ON 161-KV DISCONNECTING SWITCHES

A. M. McNerney
Associate Member AIEE
Tennessee Valley Authority
Knoxville, Tenn.

A paper recommended by the AIEE Committee on Switchgear and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31-February 4, 1955. Manuscript submitted September 30, 1954; made available for printing October 27, 1954.

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55-9

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Mechanics

Transactions Paper

(Reviewed and Accepted for Publication)

BEHAVIOR OF HIGH VOLTAGE BUSSES AND INSULATORS DURING SHORT CIRCUITS

R. M. Milton
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Chief, Elec. Engg. Branch
Tennessee Valley Authority
Chattanooga, Tenn.

Fred Chambers
Member AIEE
Assistant to Chief Power Engineer
Tennessee Valley Authority
Chattanooga, Tenn.

A paper recommended by the AIEE Committee on Switchgear and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31-February 4, 1955. Manuscript submitted August 16, 1954; made available for printing October 27, 1954.

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Paper No.
55-11

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Equip - T&D
Mechanics

Transactions Paper

(Reviewed and Accepted for Publication)

HIGH-CURRENT TESTING OF AIR-DISCONNECT SWITCHES

B. F. Gostin
Member AIEE
Supervisor, Electrical Laboratory
Tennessee Valley Authority
Chattanooga, Tenn.

A paper recommended by the AIEE Committee on Switchgear and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31-February 4, 1955. Manuscript submitted September 20, 1954; made available for printing October 29, 1954.

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Ref. Bruce Knigsbury

Mechanics

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
WM Pafenbach, Jr.	Stress & Strain (Deflection Measurements)	56TP458
		DATE 8 - 3 - 56

TITLE

A NEW TECHNIQUE IN LARGE DEFLECTION MEASUREMENTS

FOR USE OF G-E EMPLOYEES ONLY

GENERAL ELECTRIC

TRANSFORMER AND ALLIED PRODUCTS DIVISION

Mechanics

Conference Paper

A DYNAMIC TORQUEMETER UTILIZING THE RECIPROCAL WIEDEMANN EFFECTS

M. J. O'Neill
Associate Member AIEE
The Perkin-Elmer Corporation
Norwalk, Conn.

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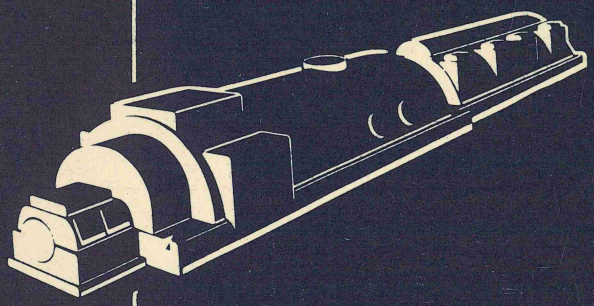
57-112



Mechanics

The Calculation of Residual Stresses in Thick Plates Using the Solution of the Problem of an Infinite Plate with a Circular Hole.

M. Gurtin

TR-57-TG-178

4-22-58

LARGE STEAM TURBINE-GENERATOR DEPARTMENT

GENERAL ELECTRIC

SCHENECTADY, N. Y.

Ehw

OPERATING 300 KV.

IN QUEBEC

BY

H.W. HABERL

ASSISTANT CHIEF ENGINEER

QUEBEC HYDRO ELECTRIC POWER COMMISSION

MONTREAL - QUEBEC

CANADA

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
JG Anderson	Transmission Lines	58-PT-373
		DATE 4/16/58

TITLE
Preliminary Insulation Estimates for the G. E. Extra-High Voltage Project

Frey
Weller
Walters
Kamunko
Tesatko
Kingsbury
File Evaline

FOR USE OF G-E EMPLOYEES ONLY

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TRANSFORMER AND ALLIED PRODUCTS DIVISION

4

EHV

345 KV DOUBLE CIRCUIT TRANSMISSION

David Burns - The Detroit Edison Company

Edison Electric Institute
Transmission and Distribution Committee
Muehlebach Hotel
Kansas City, Missouri
May 2, 1957

W Bodenstein

PAPER NO. 13-2

INFLUENCE OF TOWER DESIGNS ON TRANSMISSION-LINE LIGHTNING PERFORMANCE

By F. A. Fisher
J. G. Anderson

SOUTHWESTERN IEEE CONFERENCE
Dallas, Texas

April 20, 1967

EHV

FIELD CONTROL OF INSULATORS FOR MODERN HIGH VOLTAGE LINES

BY

JOHN M. SHEADEL
DEVELOPMENT ENGINEER
OHIO BRASS COMPANY

PRESENTED AT THE
FALL MEETING
ELECTRICAL EQUIPMENT COMMITTEE
IN JOINT SESSION WITH
TRANSMISSION AND DISTRIBUTION COMMITTEE
PENNSYLVANIA ELECTRIC ASSOCIATION
READING, PENNSYLVANIA

OCTOBER 9, 1953

PUBLICATION NO. 1299-H

GENERAL ELECTRIC

General Installation and Operation of Kenotron Tubes

Installation

MECHANICAL

The handling of a kenotron in transportation and storage requires great care since the tube may be permanently damaged if subjected to shock. Each tube is suspended within its shipping carton so that it will not come in contact with the sides of the carton during shipment. The tube should be stored in the carton and should be protected from moisture and extreme temperature changes. Furthermore, while the tube is being handled it should be kept in a vertical position with the cathode end down. Under no circumstances should crated tubes be piled on top of one another.

The kenotron should be installed in a vertical position with the cathode base down.

In installations where a nonrigid anode connection is used, reasonable flexibility must be provided to prevent placing a strain on the cathode base. Since the bulb becomes hot during continuous operation, it should not come in contact with any metallic body, nor be subjected to the drops or spray of any liquid.

The accumulation of dust and metallic particles on the outer surface of the glass walls will increase the leakage over this surface. As this may result in tube failure from arc-over, periodic cleaning of these surfaces should be maintained.

When a kenotron is operated at voltages above 75 kv peak inverse, harmful x-rays may be generated. Adequate protection against these x-rays should be provided.

COOLING

Free circulation of cool air around the glass bulb should be maintained. High-temperature air from other apparatus should be prevented from circulating around the tubes. If desired the tubes may be immersed in a tank of oil with the transformers.

---

*Note: The ratings and characteristics of a particular tube are given under Technical Information on the Description and Rating Sheet for that tube.

ELECTRICAL

Filament power should be supplied from a filament lighting transformer insulated for the proper voltage. This transformer should be provided with a secondary midtap for the plate circuit return lead. The filament excitation supply must be provided with suitable resistors or other regulating devices to apply the power to the filament gradually and to adjust it accurately during operation. The filament voltage should be measured directly at the filament terminals.

The high initial rush of current through the filament when the switch is first closed should be limited by the use of some form of filament starter. The proper use of the filament regulating devices will prevent this initial rush of current from destroying the filament. In any case, the current through the filament should never, even instantaneously, exceed twice the *rated value.

When the apparatus in which the tube is used is to be idle for periods not exceeding two hours, voltage should be maintained on the filament. However, if desired, provision may be made to reduce the filament voltage to approximately 80 per cent of the *rated value during "standbys." Where stand-by periods exceed two hours the filament voltage may be removed.

The plate circuit should be provided with a time-delay relay which will prevent application of plate voltage until the filament has reached normal operating temperature.

Automatic protective devices should be installed to prevent over-plate-voltage, over-plate-current, or under-filament-voltage conditions.

In the case of multi-phase installations, the plate transformer is usually designed for rectifier use. In the case of a double Y rectifier, the use of an inter-phase transformer is recommended. The cathode base should not be connected to ground or to any other part of the circuit.

The installation of all wires and connections should be made so that they do not lie on or close to the glass of the kenotron. An air space of approximately the length of the tube should be main-

Tidd 500-Kv Test Project

Transmission of Electric Power at Extra High Voltages
and
Field Test Facilities
to Study
Corona, Radio Influence, and Other Features

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Ohio Brass Company
Westinghouse Electric Corporation

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OHIO EDISON 345 KV SYSTEM

LYNN FIRESTONE
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OHIO EDISON COMPANY
AKRON, OHIO

E. A. ROTHFUS
CHIEF ELECTRICAL ENGINEER
OHIO EDISON COMPANY
AKRON, OHIO

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TECHNICAL INFORMATION SERIES

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CLASSIFICATION	NO.
H. K. Farr (for R.P.B.) R. P. Bass	Bushings – Capacitors	50TP170-1
		DATE 7/19/51

TITLE

The Operation of 5 Kv Glass and Porcelain Bushings in Salt-Fog Atmosphere. Report II

4

FOR USE OF G-E EMPLOYEES ONLY

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TECHNICAL INFORMATION SERIES

AUTHOR	SUBJECT CLASSIFICATION	NO.
G. Camilli W.P. Tootill	BUSHINGS	51TP1325
		DATE 5-1-51

TITLE Bushings for Low Voltage Circuits.

ABSTRACT

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GENERAL ELECTRIC

TRANSFORMER AND ALLIED PRODUCT DIVISIONS

Transactions Paper

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LIGHTNING REFERENCE BIBLIOGRAPHY 1950-1960

AIEE Working Group of the Lightning and Insulation Subcommittee
of the
AIEE Transmission and Distribution Committee

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Summer General Meeting, Denver, Colo., June 17-22, 1962. Manuscript submitted March 19, 1962; made available for printing April 27, 1962.

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SUPERSEDING
31 December 1958
MIL-STD-105A
11 September 1950
APPENDIX
27 April 1955

MILITARY STANDARD

SAMPLING PROCEDURES AND TABLES FOR INSPECTION BY ATTRIBUTES

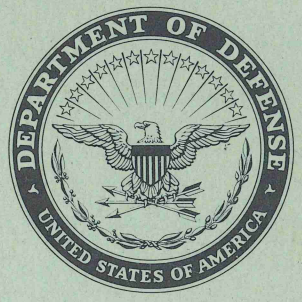
R. WELLER

MIL-STD-105A
11 September 1950

SUPERSEDING
JAN-STD-105
16 February 1949

MILITARY STANDARD

SAMPLING PROCEDURES AND TABLES FOR INSPECTION BY ATTRIBUTES



QUALITY CONTROL REPORTS

No. 9 September 1945

Statistical Quality Control at Lockheed

By

James R. Crawford

and

Preston C. Hammer

Issued by
Quality Control Program, Carnegie Institute of Technology
Pittsburgh 13, Pennsylvania
for Office of Production Research and Development
War Production Board

QUALITY CONTROL REPORTS

No. 12 September 1945

Some Experiments Illustrating Principles of Quality Control

By

Irving W. Burr

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Quality Control Program, Carnegie Institute of Technology
Pittsburgh 13, Pennsylvania
for Office of Production Research and Development
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Statistical Quality Control at the St. Louis Division of American Stove Company

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Statistical Quality Control in Radio Manufacture

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Fred Trowbridge

and

John T. Clark

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Pittsburgh 13, Pennsylvania
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An Application of Statistical Quality Control at the Hoover Ball and Bearing Company

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Russell C. Trombly

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War Production Board

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QUALITY CONTROL REPORTS

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An Adaptation of Statistical Quality Control at Aldens'

By

James M. Ballowe

Issued by
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for Office of Production Research and Development
War Production Board

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QUALITY CONTROL REPORTS

No. 1

May 1945

Introduction of Statistical Quality Control at Illinois Testing Laboratories

By

James A. Fizzell

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3-46905 P1 of 9 bu-ees-wp

Transactions Paper

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DISCUSSION IN QUADRUPLICATE DUE February 14, 1969.

FLASHOVER PROBABILITY OF PARALLEL MULTI-GAP

Toshio Suzuki
Central Research Institute
of Electric Power Industry
Tokyo, Japan

Isamu Kishijima
Central Research Institute
of Electric Power Industry
Tokyo, Japan

Yunosuke Ohuch
Tokyo Electric Power Co.
Tokyo, Japan

Koichiro Anjo
Chubu Electric Power Co.
Nagoya, Japan.

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Transactions Paper

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DISCUSSION IN QUADRUPLICATE DUE February 14, 1969.

THE METHOD OF MAXIMUM LIKELIHOOD APPLIED TO THE ANALYSIS OF FLASHOVER DATA

Gordon W. Brown
Member IEEE
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TESTING FOR NORMALITY WITH SPECIFIED PARAMETERS

by

S. S. Shapiro and M. B. Wilk*
Information Sciences Laboratory

Report No. 67-C-323

August 1967

*Bell Telephone Laboratories, Inc.

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W. B. Nelson, Information Sciences Laboratory

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PREDICTION INTERVALS TO CONTAIN FUTURE MEANS AND SOME OTHER STATISTICAL INTERVALS

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G. J. Hahn
Information Sciences Laboratory

Report No. 70-C-270

July 1970

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
CORPORATE RESEARCH AND DEVELOPMENT
Schenectady, N.Y.

A SURVEY OF PREDICTION INTERVALS AND THEIR APPLICATIONS

by

G. J. Hahn and W. B. Nelson
Information Science and Engineering

Report No. 72CRD027 January 1972

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G. J. Hahn
Information Science and Engineering

Report No. 72CRD274 September 1972

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FACTORS FOR CALCULATING TWO-SIDED PREDICTION INTERVALS FOR SAMPLES FROM A NORMAL DISTRIBUTION

by

G J. Hahn, Information Sciences Laboratory

Report No. 68-C-392 October 1968

STATISTICAL ANALYSIS OF 1967 20,000 LB. SUSPENSION INSULATOR M&E TEST DATA

May 17, 1968

by
W. B. Lounsbury

Insulator Department

Manufacturing Problems Analysis-I

GENERAL ELECTRIC

Mathematical

GENERAL ELECTRIC

DEFENSE ELECTRONICS DIVISION

TECHNICAL INFORMATION SERIES

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AUTHOR H. J. Lyness, A. E. P.

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GENERAL ELECTRIC

Transactions Paper

(Reviewed and Accepted for Publication)

A NEW APPROACH TO THE CALCULATION OF THE LIGHTNING PERFORMANCE OF TRANSMISSION LINES

Theory

C. F. Wagner
Fellow AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25-29, 1956. Manuscript submitted March 28, 1956; made available for printing May 15, 1956.

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Transactions Paper

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SAFE CLEARANCES AND PROTECTION AGAINST SHOCKS DURING LIVE LINE WORK

A. Elek
Associate Member AIEE

J. W. Simpson
Associate Member AIEE

Both of:
The Hydro-Electric Power Commission
of Ontario
Toronto, Ont., Canada

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Transactions Paper

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A NEW APPROACH TO THE CALCULATION OF THE LIGHTNING PERFORMANCE OF TRANSMISSION LINES

C. F. Wagner
Fellow AIEE
Westinghouse Electric Corp.
East Pittsburgh, Pa.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, San Francisco, Calif., June 25-29, 1956. Manuscript submitted March 28, 1956; made available for printing May 15, 1956.

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Paper No.
56-733

Discussion in Duplicate Due July 11, 1956.

District Conference Paper

Misc.

CONTROL OF FLICKER ON DISTRIBUTION SYSTEMS

L. R. Gardner
Associate Member AIEE
Houston Lighting and Power Co.
Houston, Tex.

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Associate Member AIEE
University of Houston
Houston, Tex.

Submitted in abstract or outline form only to the AIEE Transmission and Distribution Committee for presentation at the AIEE Southwest District Meeting, Houston, Tex., April 4-6, 1960. Manuscript submitted February 1, 1960; made available for printing February 10, 1960.

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60-530

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Some Fundamental Aspects of Recovery Voltages

J. ZABORSZKY
MEMBER AIEE

J. W. RITTENHOUSE
FELLOW AIEE

Summary: Whether any load-interrupter switch successfully interrupts when called upon to do so depends solely upon how the recovery voltage builds up across the switch as a function of time in comparison with the build-up of dielectric strength between the switch contacts. This paper deals with recovery voltages in a graphical manner, so that a visual concept of recovery voltage versus time across a switch is provided in both single- and 3-phase cases involving resistive loads, inductive loads, and capacitive loads. As a special case, the recovery voltage across a switch in a loop-sectionalizing application is also treated in this paper.

IN RECENT DECADES electric load densities in the United States have been increasing at exceedingly high rates. This has gradually produced increased interest in the basic fundamentals relating to load interruption.

It is the purpose of this paper to demonstrate some of the fundamental properties of recovery voltages in relation to different kinds of switching problems, with a view to demonstrating the differences in voltage conditions to which load-interrupter equipment might be subjected.

The treatment will illustrate the well-known fact that the ability of a given commercial product to interrupt a flow of power is as much a function of the circuit containing the switch as of the design of the switch itself.

It is hoped that the simplified and sequential approach presented here will serve as a stimulus for future extension of this review.

Paper 62-244, recommended by the AIEE Switchgear Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., January 28–February 2, 1962. Manuscript submitted August 1, 1961; made available for printing December 8, 1961.

J. ZABORSZKY is with Washington University, St. Louis, Mo., and J. W. RITTENHOUSE is with the Hi-Voltage Equipment Company, Cleveland, Ohio.

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AIEE
Technical Paper
47-241

September 1947
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TRANSMISSION OF ELECTRIC POWER AT EXTRA-HIGH VOLTAGES

Philip Sporn
Fellow AIEE

American Gas and Electric Service Corp.,
New York, N. Y.

A. C. Monteith
Fellow AIEE

Westinghouse Electric Corporation,
East Pittsburgh, Pa.

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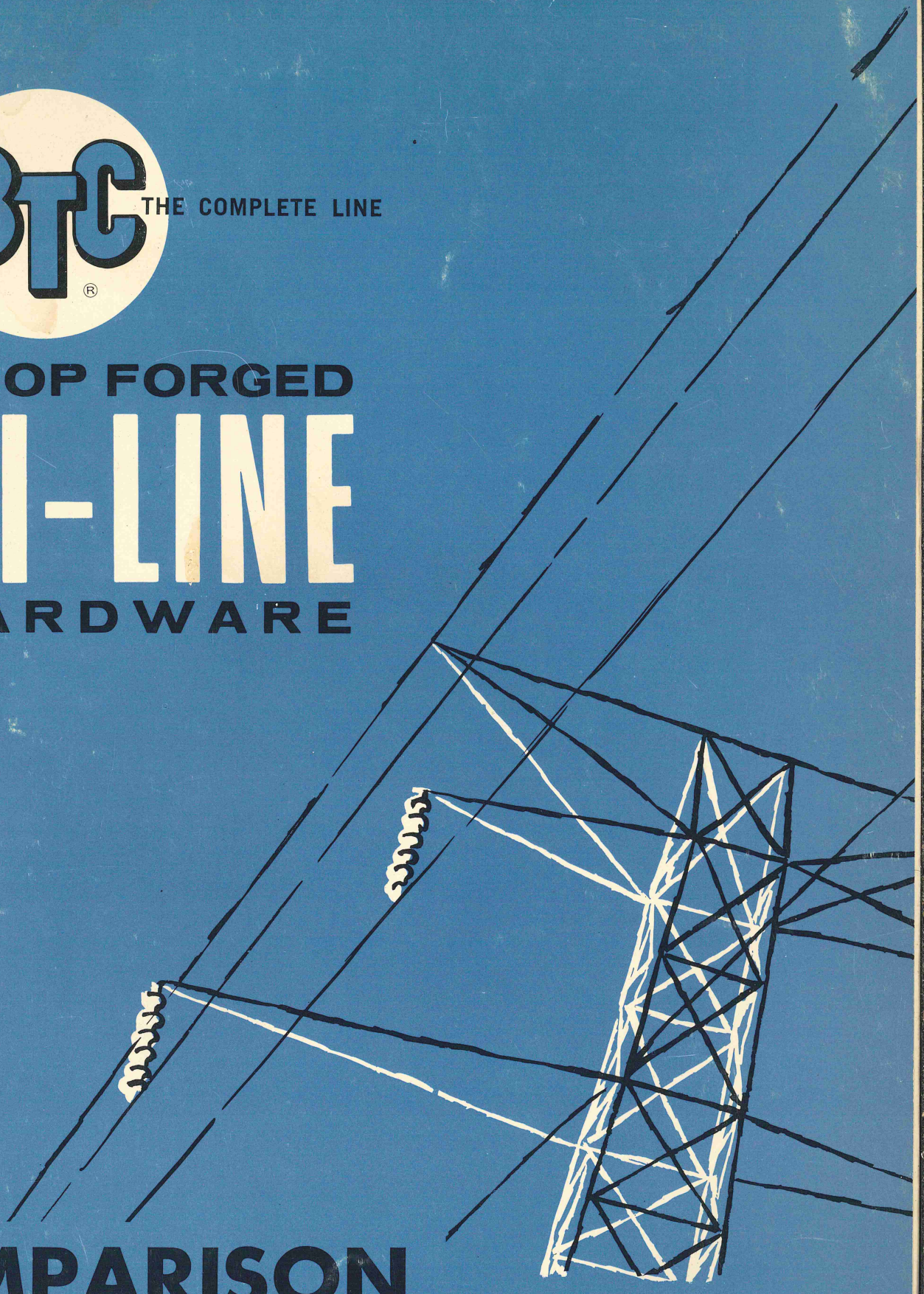

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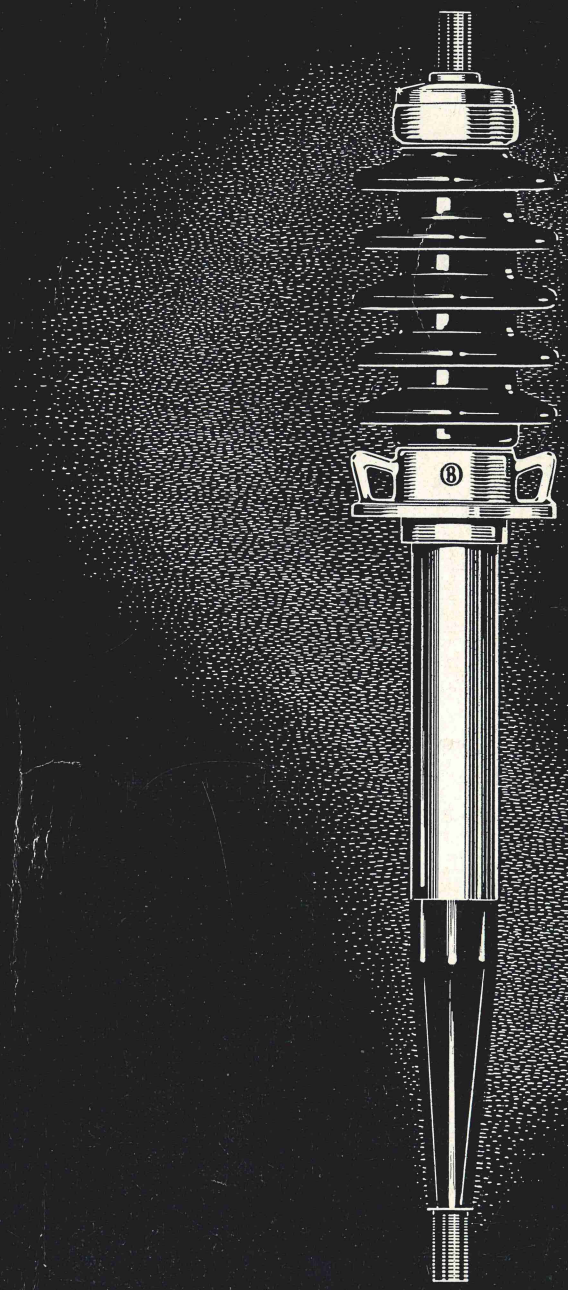

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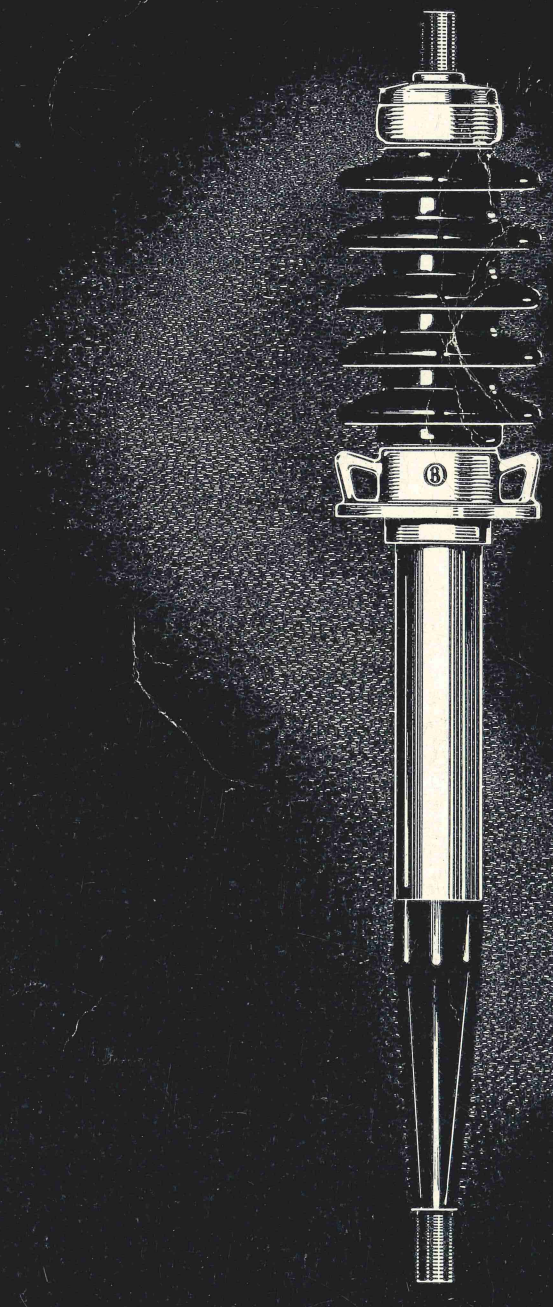

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H. P. St. Clair
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R. L. McCoy
AIEE
Technical Paper
51-224

May 1951
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LINE INSULATOR LOSS UNDER NORMAL CONDITIONS — 500-KV TEST PROJECT OF THE AMERICAN GAS AND ELECTRIC COMPANY

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DIELECTRIC AND OTHER PROBLEMS IN THE DESIGN OF A NEW 330 KV OUTDOOR AIR SWITCH

A. H. Powell
Member AIEE
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RESEARCH FOR THE ELECTRIC POWER AND ELECTRIC UTILITY INDUSTRIES IN SWEDEN

Gunnar Jancke
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Ivar Herlitz
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Stockholm, Sweden

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EXTRA-HIGH-VOLTAGE CABLE RESEARCH --

CHALLENGE OF THE FUTURE

Clement S. Schifreen
Fellow AIEE
Philadelphia Electric Company
Philadelphia, Pa.

A paper recommended by the Electrical Program Commiteee of the American Power Conference and approved for presentation at the American Power Conference, Chicago, Ill., March 31-April 2, 1959. Manuscript submitted January 26, 1959; made available for printing January 30, 1959.

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TP Project EHV - Preliminary Corona Investigations; The Effect of Harmonics on Corona Losses by A. H. Foley, Associate Member AIEE, and F. Olsen, Nonmember AIEE. (Discussion in Duplicate Due February 19, 1960.)

CP Project EHV - Technical Plan by P. A. Abetti, Member AIEE; D. D. Davis, Member AIEE; and J. H. Hagenguth, Fellow AIEE

CP Project EHV - Insulation Design by J. G. Anderson, Member AIEE; J. H. Hagenguth, Fellow AIEE; I. B. Johnson, Fellow AIEE; A. J. Schultz, Member AIEE

CP Project EHV - North Station and Portal-Type Towers by S. Minneci, Member AIEE; A. H. Powell, Member AIEE; R. E. Larson, Associate Member AIEE; G. E. Fortney, Nonmember AIEE; S. D. Alpert, Nonmember AIEE

CP Project EHV - Conductors, Insulators and Conductor Accessories by J. J. LaForest, Associate Member AIEE; J. Kaminski, Jr., Member AIEE; R. E. Larson, Associate Member AIEE

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A STUDY OF USE OF ALUMINUM GUYED TOWERS

FOR EXTRA HIGH VOLTAGE TRANSMISSION SYSTEMS

L. H. J. Cook
Member AIEE

B. Cooper

Both of:
International Power and Engineering
Consultants Limited
Vancouver, Canada

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EXPERIMENTS WITH GALLOPING SPANS

James J. Ratkowski
Associate Member AIEE
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Conference Paper

RESEARCH AND DEVELOPMENT LEADING TO THE HIGH-POWER VACUUM INTERRUPTER -- AN HISTORICAL REVIEW

J. D. Cobine
Member AIEE
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Paper No. **CP 62-67**

Transactions Paper

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PERFORMANCE OF 161-KV AND 115-KV TRANSMISSION LINES

Fred Chambers
Member AIEE

C. P. Almon, Jr.
Fellow AIEE

Both of:
Tennessee Valley Authority
Chattanooga, Tenn.

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R.L. McCoy Jan 28, 1962

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RADIO NOISE FROM HIGH-VOLTAGE TRANSMISSION LINES

AIEE Radio Noise Subcommittee
of the
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Members of the AIEE Radio Noise Subcommittee: H. L. Rorden, Chairman; L. O. Barthold, P. L. Bellaschi, H. H. Brustle, F. C. Creed, F. R. Dallye, H. M. Ellis, C. D. Fiero, H. A. Gauper, E. H. Gehrig, R. E. Graham, F. L. Greene, N. S. Kent, J. J. LaForest, J. R. Leslie, T. W. Liao, R. J. Mather, C. J. Miller, A. C. Neaderland, W. E. Pakala, B. M. Pickens, M. G. Poland, L. M. Robertson, R. H. Schlomann, L. N. Stone, E. R. Taylor, F. L. Taylor, F. J. Trebby, P. D. Tuttle, F. C. Vose, F. A. Denbrock, H. M. Mather.

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CATHODE EFFECTS IN THE DIELECTRIC BREAKDOWN OF LIQUIDS

by

J. K. Bragg, A. H. Sharbaugh, and R. W. Crowe

Report No. RL-953 September 1953

CLASS 1

SCHENECTADY, NEW YORK

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ON THE TOWNSEND MECHANISM OF SPARK BREAKDOWN OF GASES

by

R.W. Crowe, J.K. Bragg and V.G. Thomas

Report No. RL-1011 January 1954

CLASS 1

SCHENECTADY, NEW YORK

Space Charge Phenomena in Liquid Dielectrics

By D. W. GOODWIN†
Department of Physics, The University of Birmingham

Communicated by K. A. Macfadyen; MS. received 19th August 1955

Abstract. By means of the electro-optical Kerr effect, distortion by space charge of the uniform potential gradient between electrodes in purified chlorbenzene has been observed. Evidence is presented suggesting that the conduction process occurs in filaments. The modified distribution of field strength is in qualitative agreement with a previous theory.

§ 1. Introduction

A theory of electrical breakdown in liquid dielectrics (Goodwin and Macfadyen 1953) suggests that field distortion is produced in a liquid at high field strengths as a result of electron emission from the cathode and the movement of ions between the electrodes. One important prediction of this theory is that the cathode field strength becomes enhanced in comparison with the anode field strength as the applied field strength is increased to that value required to produce breakdown. It is the purpose of this paper to describe investigations into such an increase in cathode field strength and to compare its magnitude with the predicted value.

Space charge effects in liquids have been observed previously (Dantscher 1931, Vafiadis 1939) using the Kerr electro-optical effect under conditions of continuously applied fields. In the experiments to be described space-charge effects, resulting from the application of rectangular voltage pulses, have been revealed using the Kerr effect. The use of pulsed voltages has been shown previously to overcome experimental difficulties associated with liquids under high electric stress.

§ 2. Apparatus and Experimental Method

2.1. *The Experimental Method*

The application of a strong electric field to an insulating liquid will make it doubly refracting. If now light, plane polarized in a direction at 45° to that of the electric field, passes through the liquid it will be elliptically polarized. The phase difference Δ between the two components is given by Kerr's law

$$\Delta = BlE^2 \qquad \ldots\ldots(1)$$

where l is the distance the light travels through a field of strength E; B is known as Kerr's constant. Transmission can then occur through an analyser crossed with the polarizer under zero field strength conditions. Differences in transmission across the gap can be correlated with space charge phenomena (Dillon 1930). The phase difference Δ can be measured with a Rayleigh compensator (Rayleigh 1902), a strip of photo-elastic material under cantilever

† Now at the Radar Research Establishment, Great Malvern, Worcs.

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TECHNICAL INFORMATION SERIES

AUTHOR	SUBJECT CLASSIFICATION	NO.
WA Hixson W.A. Hixson	1. Dielectrics - Phenomena 2. Bushings - Power 3. Gaps - Air	52TP21
		DATE 3/10/52

TITLE

Effect of Ground Plane Protrusions on the Sixty-Cycle and Impulse Flashover Mechanism of Bushings.

ABSTRACT

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R. S. Norman
Associate Member AIEE

A. A. Kessel
Nonmember AIEE

Both of:
General Electric Company
West Lynn, Mass.

A paper recommended by the AIEE Dielectrics Committee for the AIEE Winter General Meeting, New York, N. Y., February 2-7, 1958. Manuscript submitted October 14, 1957; made available for printing December 6, 1957.

Price: 40¢ To Members
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AUTHOR A. E. DURKIN
THOMSON LABORATORY

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K. H. Kidd
Associate AIEE
The Hydro-Electric Power Commission of Ontario
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A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ont., Canada, June 25-29, 1951. Manuscript submitted March 27, 1951; made available for printing May 16, 1951.

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TIME-SHARING COMPUTER PROGRAMS FOR ESTIMATING PARAMETERS OF SEVERAL NORMAL POPULATIONS AND FOR REGRESSION ESTIMATION FROM CENSORED DATA

by

G.J. Hahn and J.M. Miller*
Information Sciences Laboratory

Report No. 68-C-366 September 1968

*Telecommunications and Information Processing Operations,
2500 Cambridge Road, Schenectady, N.Y.

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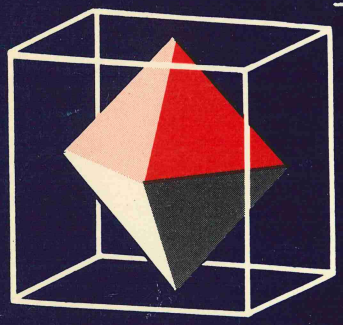

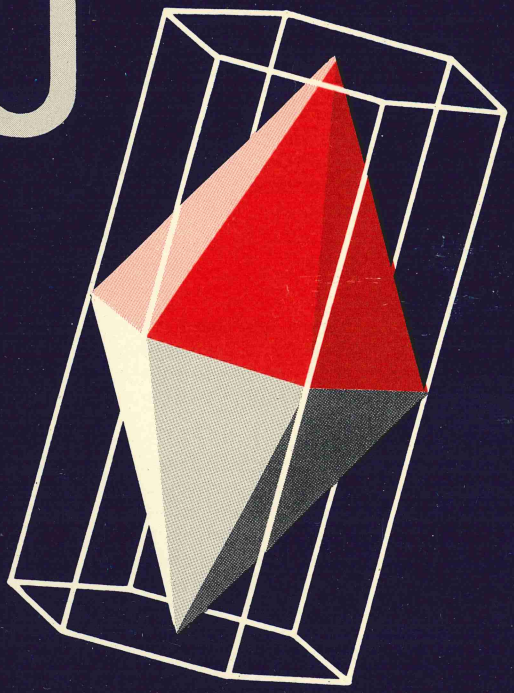

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Porcelain for High Voltage Insulators

In this paper the mechanical failure of porcelain is discussed with special reference to 3 seldom recognized characteristics: the effect of the porcelain surface on the strength, the apparent anomalous distribution of individual mechanical test values, and the effect of time on mechanical strength. A method of evaluating the result of these factors on electrical insulator performance is suggested.

By
D. H. ROWLAND
ASSOCIATE A.I.E.E.

Locke Insulator Corp., Baltimore, Md.

THERE CAN BE little argument as to what mechanical characteristics are desirable in high voltage insulators, but the factors which contribute to such characteristics are concealed, more often than not, by an extraordinary amount of sophistic data. Modern high voltage insulators on the average have improved enormously in the past decade. This improvement has been brought about in most cases by expensive and tedious cut and try tests conducted on assembled insulators. The procedure has been to assume that certain features of the completed units such as mechanical strength, ability to withstand immersion first in boiling water and then in ice water, imperviousness to moisture, and other qualities would insure insulators capable of standing up in service, which, after all, is the only real criterion of insulator worth. Finally specifications such as the A.I.E.E. Standards No. 41 for the testing of high voltage insulators were evolved and it may here be stated, unequivocally, that insulators which will successfully pass these specifications will give an unusually good account of themselves in the field. However, just because 2 groups of insulators of different manufacture successfully pass a certain specification it cannot be assumed that their maintenance cost in the field will be the same. How will they stand up under mechanical shock such as the impact from stones or bullets? What effect will time under load have upon their life? What is the maximum load that they will withstand? Is actual experience over a period of years the only way to find out? The purpose of this discussion is to provide engineers with a greater insight into some of the more recently investigated and rather peculiar mechanical characteristics of ceramic materials with the hope that an understanding of this work will help them to answer these questions and to point out that some of the characteristics which have been viewed with alarm by the uninitiated are really a true part of the whole scheme while other factors which have been unknown, or neglected, have been of major importance. A realization of this is bound to lead to still greater efficiency of systems dependent on the insulating qualities of such materials.

A paper recommended for publication by the A.I.E.E. committee on power transmission and distribution, and scheduled for discussion at the A.I.E.E. summer convention, Pasadena, Calif., June 22–26, 1936. Manuscript submitted March 25, 1936; released for publication April 23, 1936.

10. For numbered references see list at end of paper.

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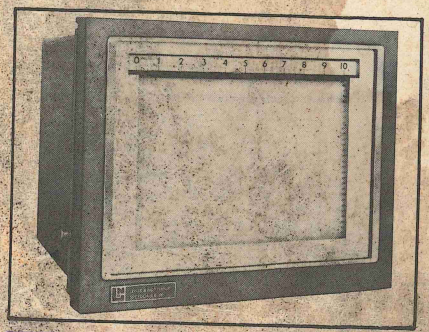

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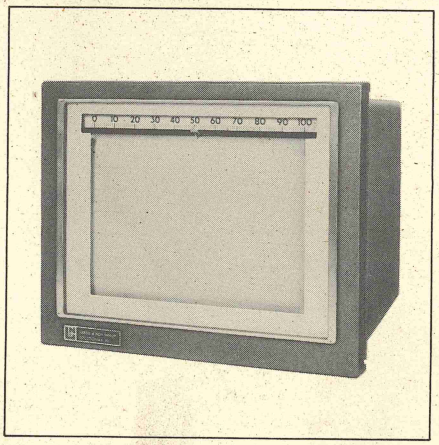

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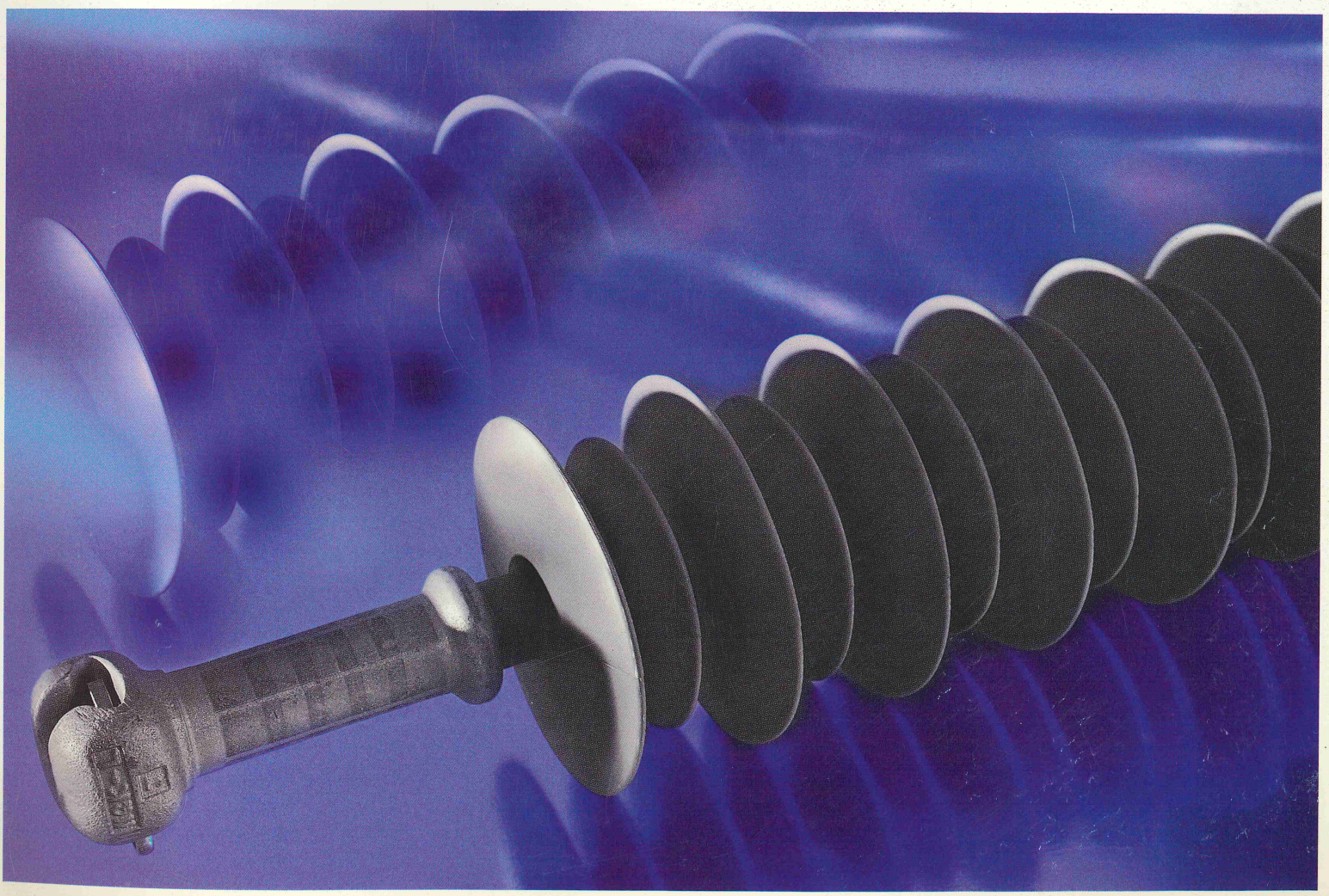

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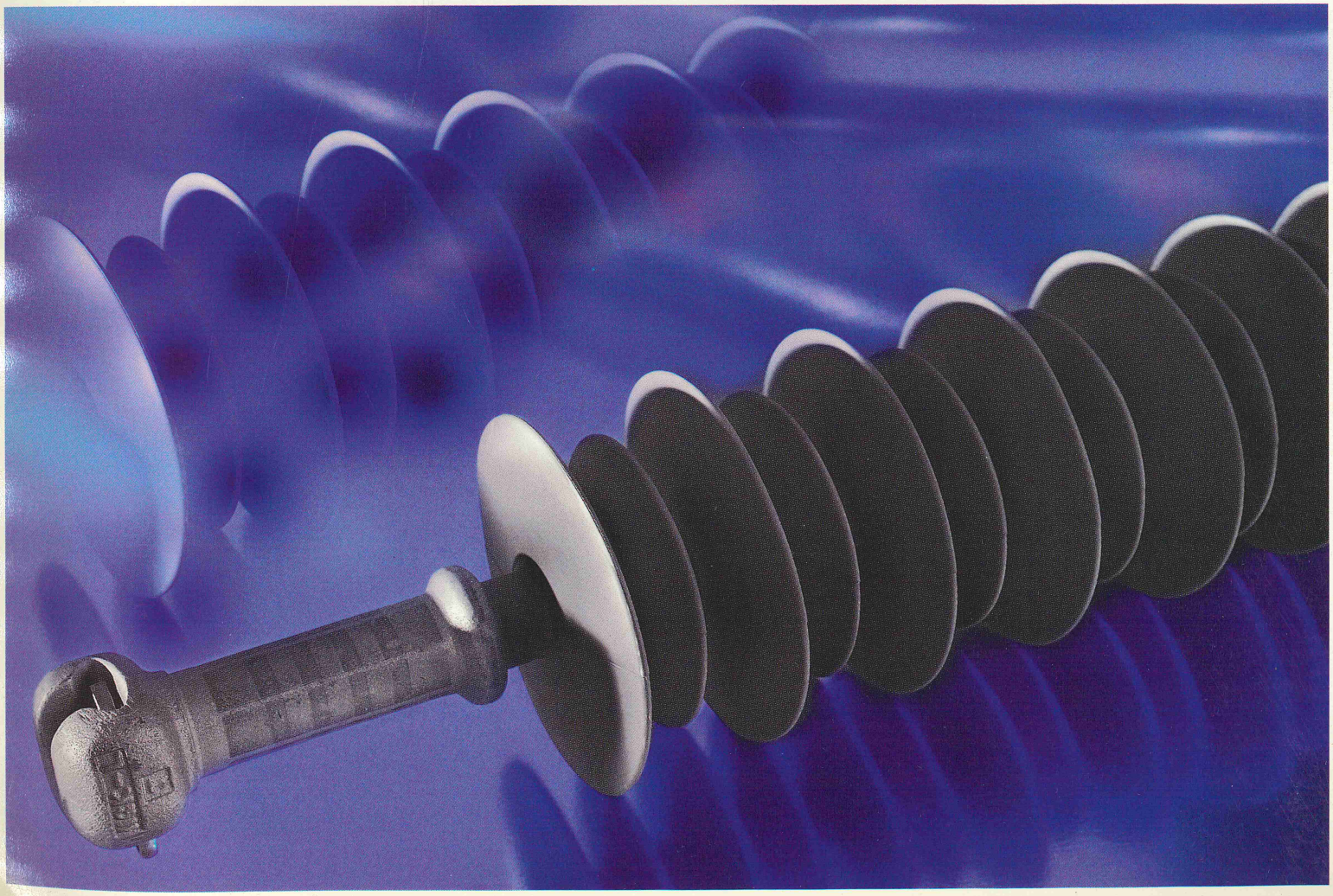

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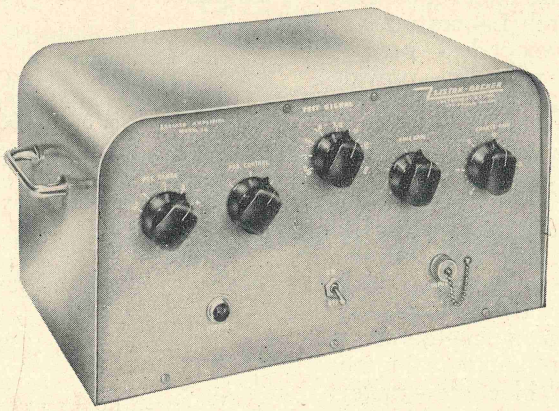

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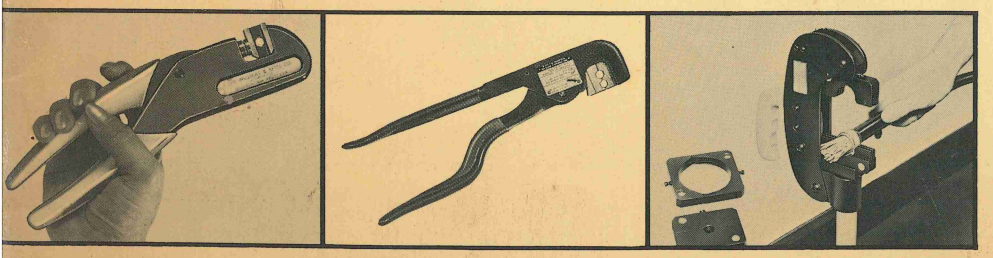

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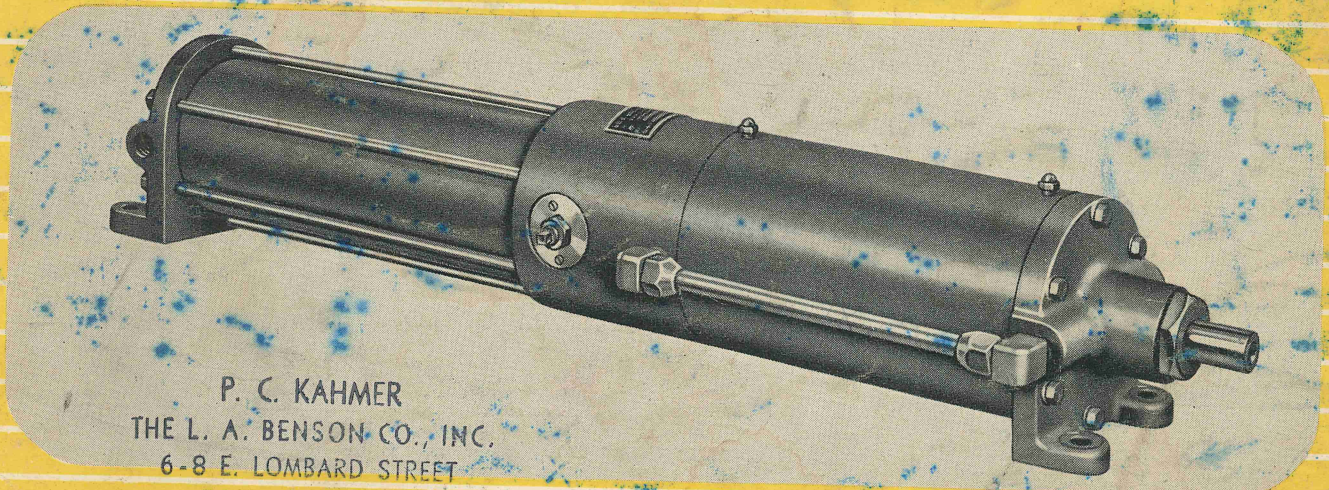

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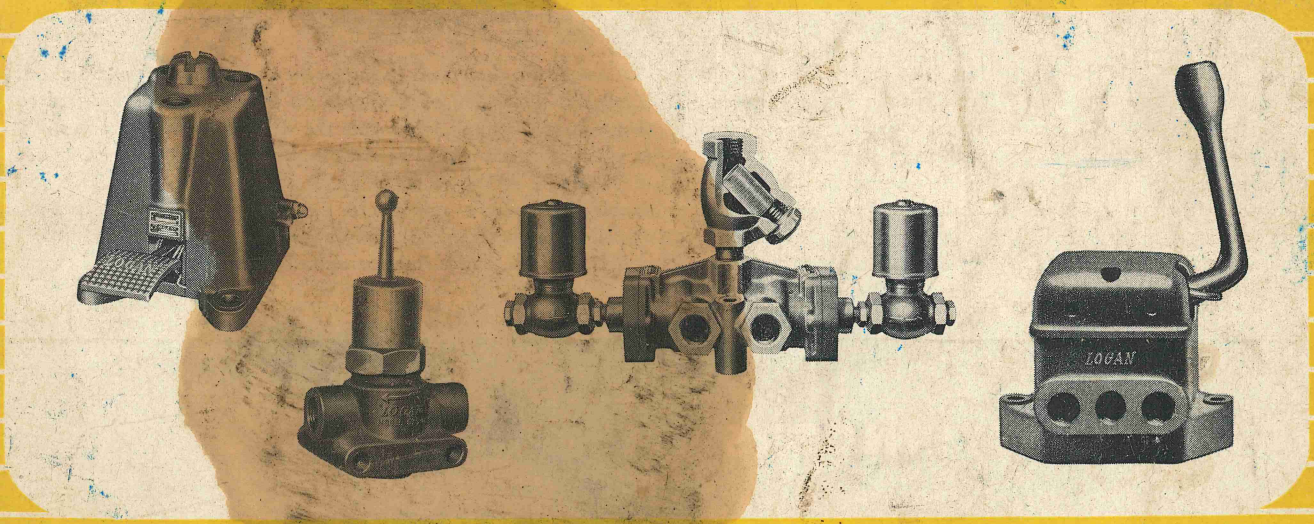

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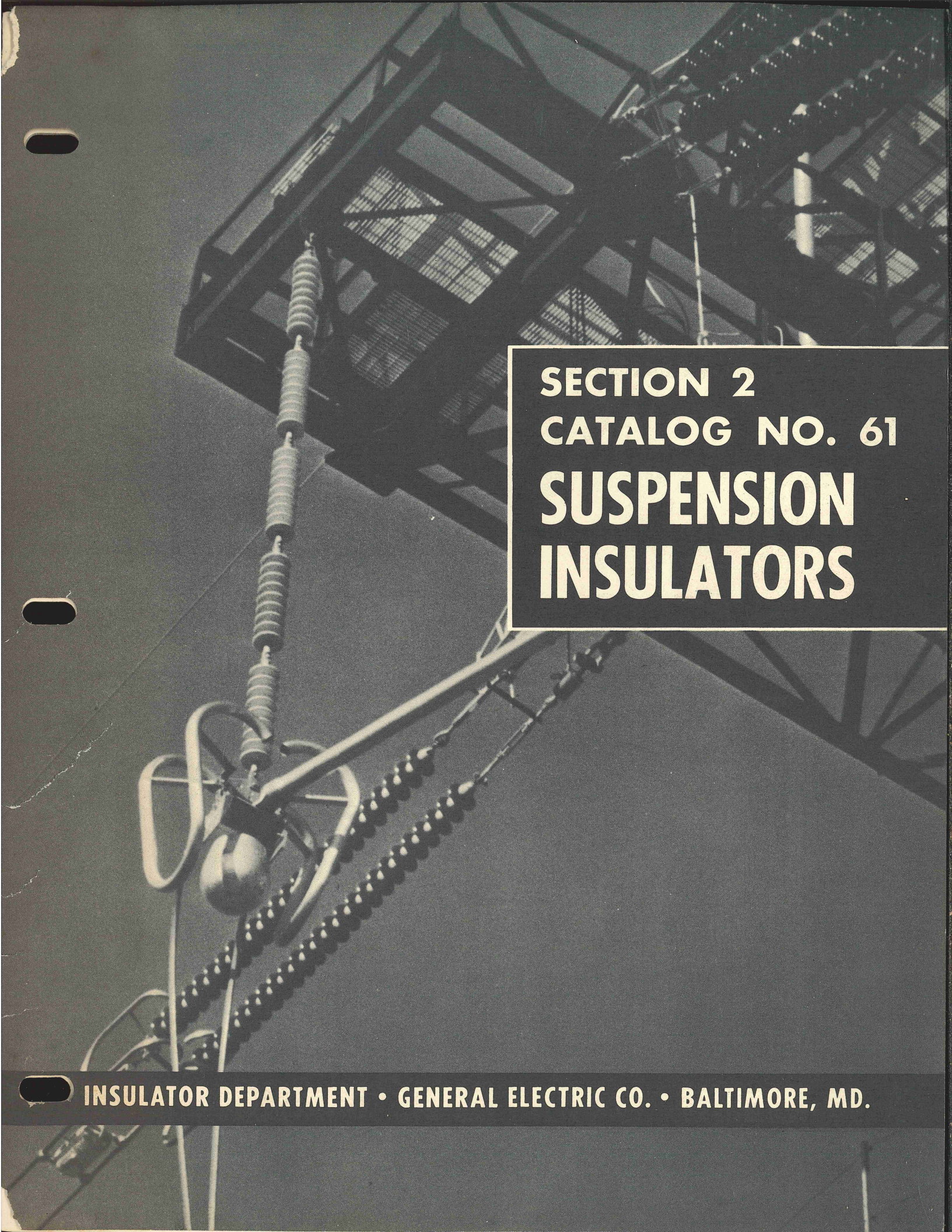

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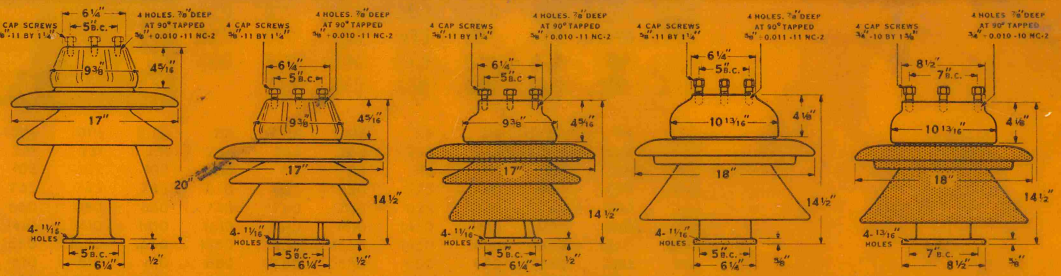

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Fatigue of Metals in Engineering and Design

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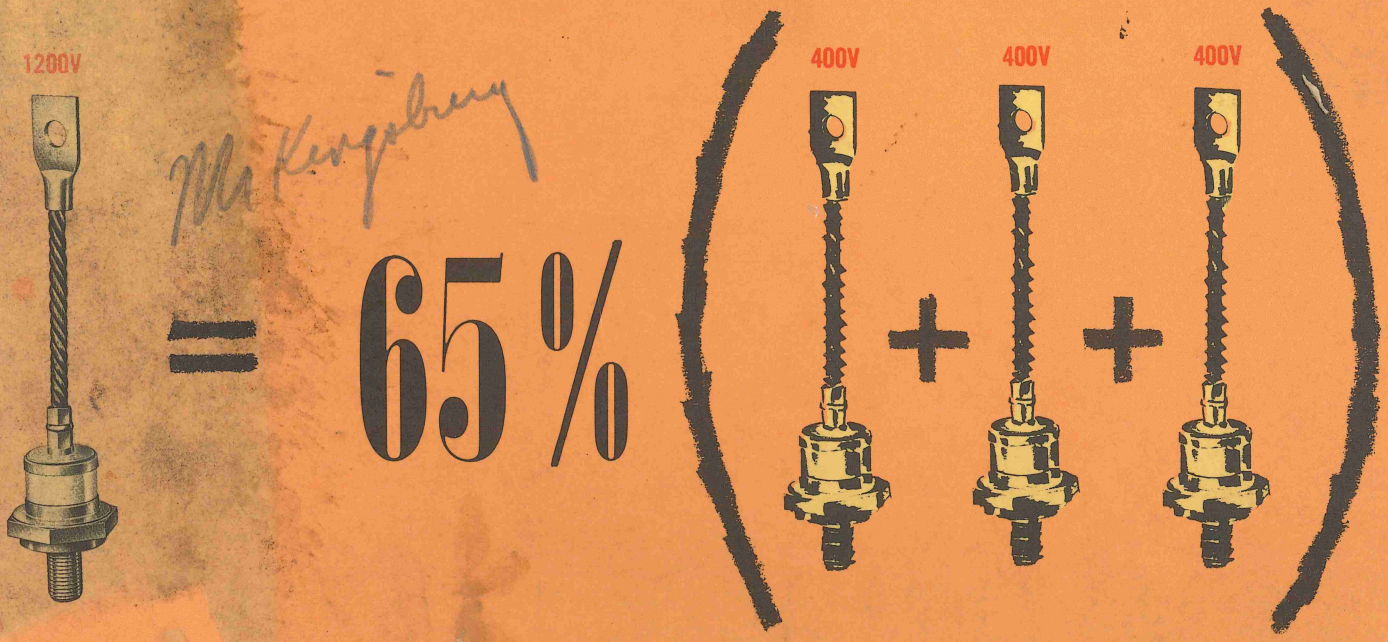

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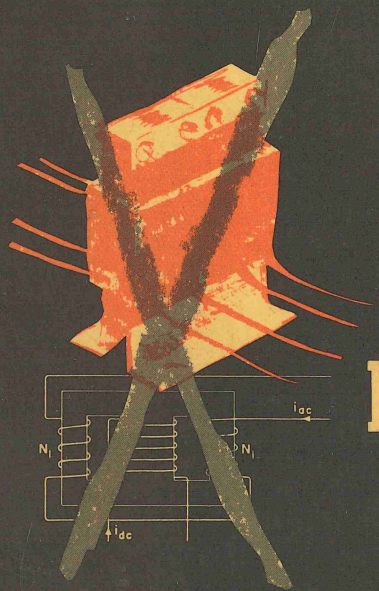

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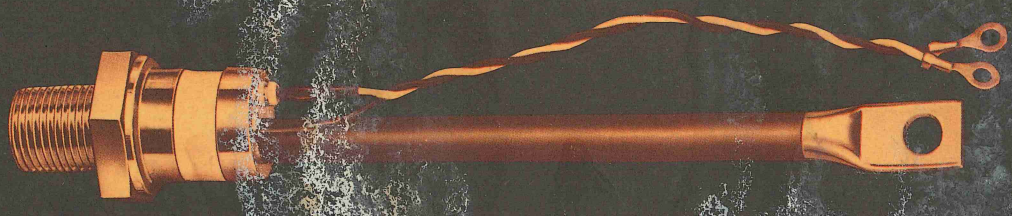

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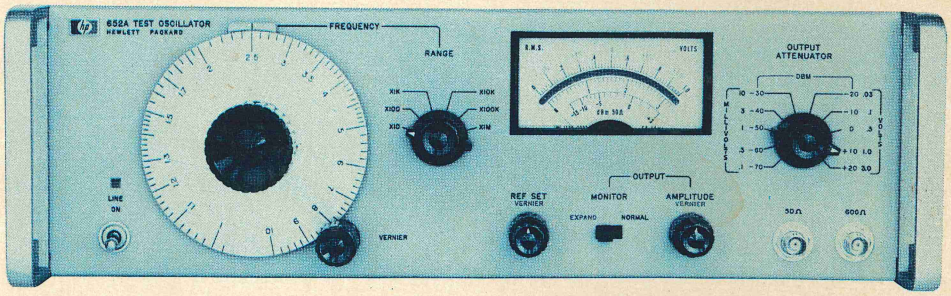

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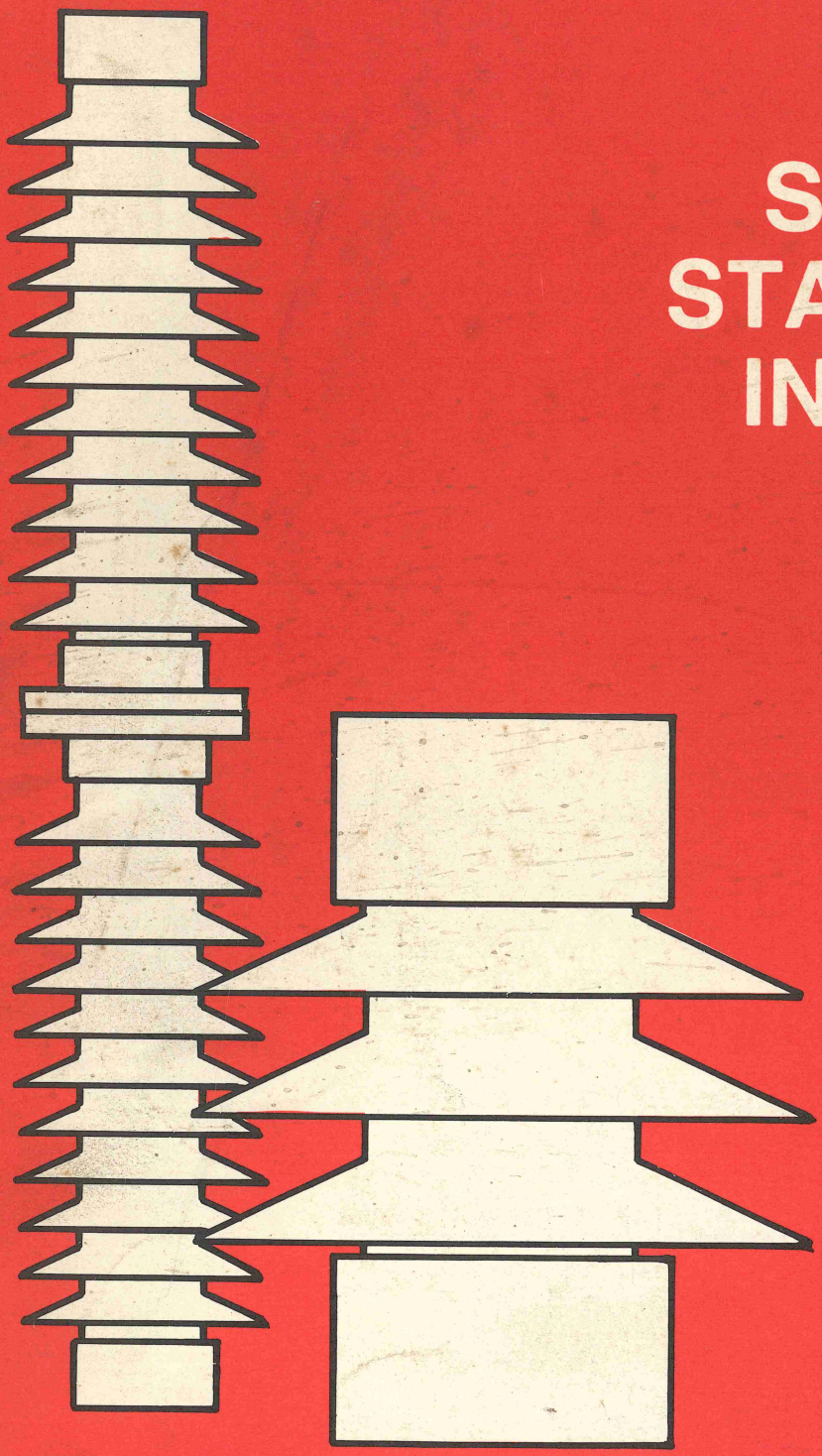

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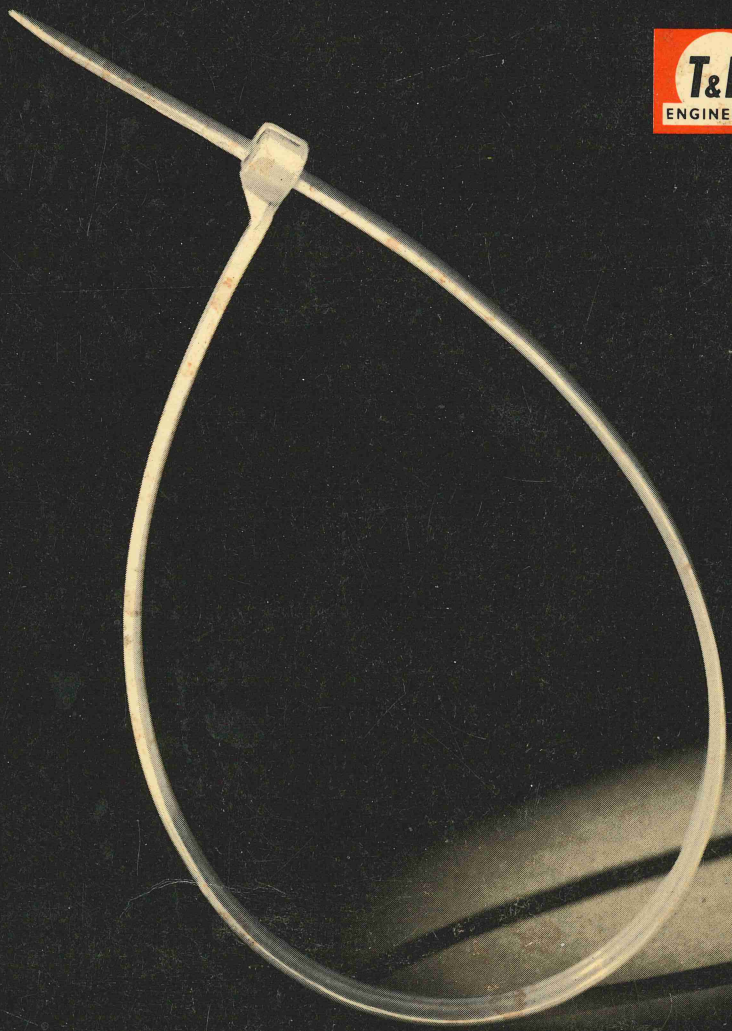

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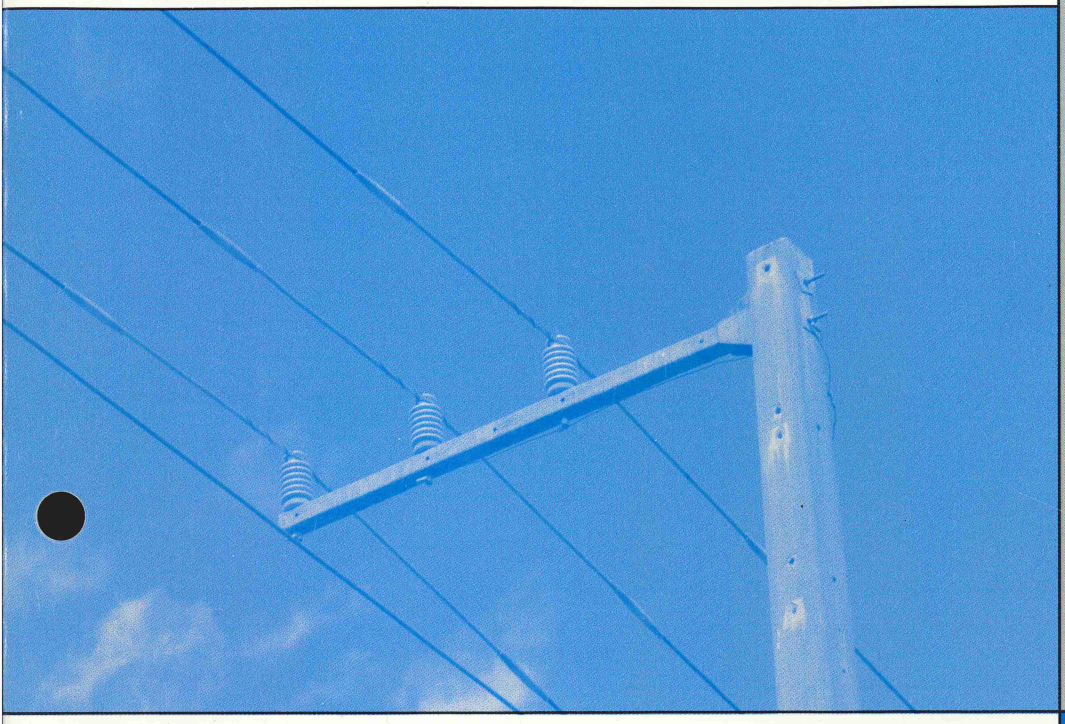

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THE INFLUENCE OF WATER RESISTIVITY AND PRECIPITATION RATE UPON 60-CYCLE WET FLASHOVER VOLTAGE

AIEE Committee Report

The Working Group on Rain Tests was appointed in January 1957, for the purpose of studying problems associated with wet flashover and wet holding tests on high voltage insulators such as are used on transmission and distribution lines. These problems are intimately concerned with the resistivity of the water used in the tests and the rate of precipitation with which it falls on the test specimen. In connection with the latter, a study of suitable methods for applying the water to the test specimen may well be an area for investigation particularly for use in wet flashover or holding tests on extra high voltage insulation.

Present European standards for wet testing specify a water resistivity of 10000 ohms per centimeter cube (3900 ohms per inch cube) and a precipitation rate of 3 millimeters per minute (0.118 inch per minute) while present American standards specify a water resistivity of 7000 ohms per inch cube and a precipitation rate of 0.2 inch per minute.

Wet flashover and wet holding voltages have been specified for practically all classes of high voltage equipment including

---

This report was prepared by the Working Group on Rain Tests of the Subcommittee on Techniques for Dielectric Tests. The personnel of this working group are: C. J. Miller, Jr., Chairman, T. L. Dyer, Jr., H. E. Fiegal, B. E. Kingsbury, and D. L. Whitehead. The material for this paper was accumulated mostly in 1938 to 1940 by the General Electric Company, The Ohio Brass Company, and the Westinghouse Electric Corporation.

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I. B. Johnson, Schenectady
A. J. Schultz, Schenectady
C. H. Titus, Philadelphia
W. R. Wilson, Philadelphia

Enclosed is a copy of the discussion which I propose to submit on the paper, "CALCULATION OF TRANSMISSION LINE LIGHTNING VOLTAGES BY FIELD CONCEPTS", by Professor Lundholm, Dick Finn, and W. S. Price at the coming Chicago Convention. I should be very much interested in any comments that you may have on it. I expect to arrive at the Morrison Hotel in Chicago late on the seventh and shall be there until after the session on the tenth.

Wilfred F. Skeats

W. F. Skeats
CONSULTING ENGINEER
ENGINEERING RESEARCH AND DEVELOPMENT LABORATORIES

Enclosure

WFS/jg

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H. A. FREY

Theory

A HYPOTHESIS CONCERNING LIGHTNING PHENOMENA AND TRANSMISSION LINE FLASHOVER

by

I. B. Johnson*
Member AIEE

A. J. Schultz*
Member AIEE

Conference Paper Presented at
AIEE Northeastern District Meeting
Pittsfield, Massachusetts

Thursday, May 2, 1957

*General Electric Company, Schenectady, New York

Paper No. DP 57-568

Theory

A HYPOTHESIS CONCERNING LIGHTNING PHENOMENA AND TRANSMISSION LINE FLASHOVER

by

I. B. Johnson*
Member AIEE

A. J. Schultz*
Member AIEE

Conference Paper Presented at
AIEE Northeastern District Meeting
Pittsfield, Massachusetts

Thursday, May 2, 1957

*General Electric Company, Schenectady, New York

Paper No. DP 57-568

AIEE DISTRICT PAPER 57-561

FACTORS AFFECTING THE LIGHTNING PERFORMANCE OF TRANSMISSION LINES

J. H. Hagenguth
Fellow - AIEE

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Member - AIEE

Power Transformer Department
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Pittsfield, Massachusetts.

Presented at the AIEE Northeastern District Meeting,
Pittsfield, Mass., May 1-3, 1957

PAPER NO.

DP 57-561

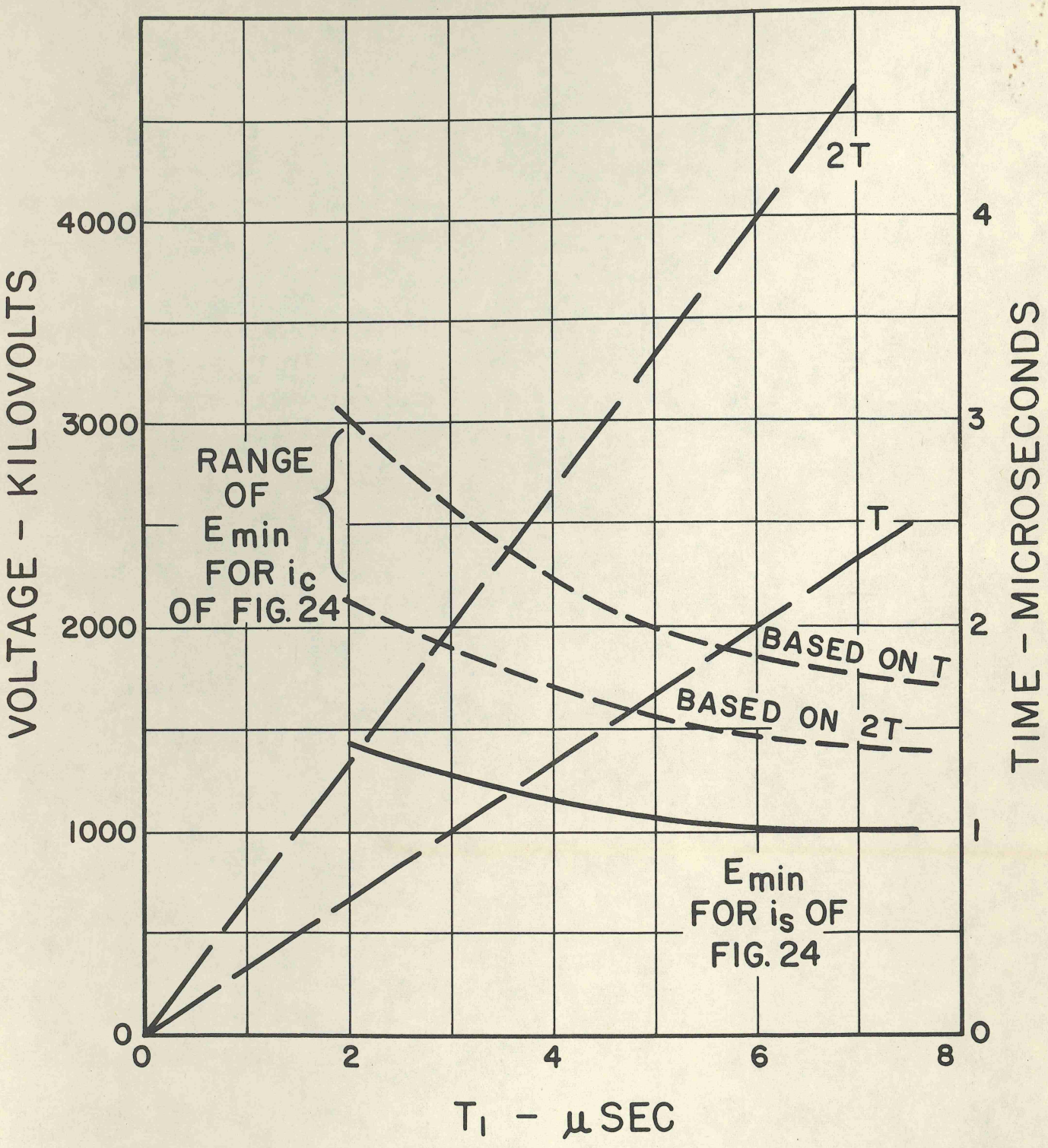

FIG. 25. MINIMUM VOLTAGES USED FOR CALCULATIONS IN FIG. 24.

CHOOSING AND USING INDUSTRIAL DATA

Francis J. Cullen
Industrial Statistician

The National Plastic Products Company
Odenton, Maryland

I am going to discuss three broad phases of Industrial Statistics and illustrate with examples from one of our products, namely, saran monofilament, widely used for seat covers and outdoor furniture which presents unique quality problems not found in other products. The basic principles which I am about to discuss, however, apply to our product and to most any other product including the products developed in the office.

The three broad phases under discussion:

I Basic Statistical Method
II Methods of Process Control
III Methods of Product Control

My discussion shall certainly not include all the techniques in these fields, but I shall try to tie together and follow Statistical Quality Control-wise one product from inception to end use while using some statistical technique from each phase listed above.

I repeat: My examples are all taken, naturally, from the Plastics industry but the basic principles apply whether we are dealing with nuts and bolts or office procedures.

I Basic Statistical Method

In Industrial Statistics basic statistical techniques are often used to define and measure patterns of variation. Statistics may be defined as a "study in variation" and the statistician is often defined as an "expert in identifying and measuring patterns of variation."

Variation is the stuff from which statistics are manufactured. By variation I refer to the inability of nature or man to produce things exactly alike. They may be alike for all practical purposes but if measured finely enough a tendency will be observed for the measurements to concentrate about one value while at the same time there is a spread of the measurements in a definite pattern on each side of the point of concentration.

Thus if we measure selected samples, plot the measurements, observe the pattern formed and compute a few statistics, we will find it much easier to analyze the data and draw proper conclusions.

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
CORPORATE RESEARCH AND DEVELOPMENT
Schenectady, N.Y.

METHODS FOR PLANNING AND ANALYZING ACCELERATED TESTS

by

W. B. Nelson
Information Science and Engineering

Report No. 73CRD034

March 1973

TECHNICAL INFORMATION SERIES

CLASS 1

This paper is for presentation at the 4th Annual Reliability and Maintainability Conference, July 28 through 30, 1965 in Los Angeles.

PROBABILISTIC LIFE CONSUMED ANALYSIS ON HIGH TEMPERATURE, HIGHLY STRESSED STRUCTURAL PARTS

By

G. W. Weber, Manager
Reliability Applications
Reliability & Design Methods Engineering
Large Jet Engine Department
General Electric Company
Cincinnati 15, Ohio.

April 9, 1965

Introduction

The reliability of complex equipment can be predicted, based on experience with similar equipment and the anticipated effects of changes in the design and application details. Frequently overall equipment goals or requirements are established on the basis of such predictions and then apportioned down to the part level to provide specific part or component reliability goals. In critical jet engine structural design areas, the part probability of failure goals are frequently of the order of .001 to .0001 per 1000 hour life or overhaul period. Classical design approaches, which are based on factor of safety criteria, cannot translate these probability numbers into design decisions regarding dimensions, material properties, stresses, etc. because they are, of necessity, deterministic

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SCHENECTADY, NEW YORK

CLASS 1

HAZARD PLOTTING FOR RELIABILITY ANALYSIS OF INCOMPLETE FAILURE DATA

by

W. B. Nelson
Information Sciences Laboratory

Report No. 68-C-313

August 1968

8-332-6185

Mark Humphrey - Tape

THE QC ANALYSIS SYSTEM

by

J. L. Bemesderfer

Presented at

R & D C Symposium on Applications of

Probability and Statistics in General Electric

Schenectady, N. Y. June 10-11, 1969

A MACHINE SHOP SIMULATION USING GPSS

April 1969

D.C. Hogue

Systems Analysis Engineer
Systems Engineering and Analysis Branch
Information Sciences Laboratory
Schenectady, N.Y.

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GENERAL ELECTRIC

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT	NO. 68 APD - 3
A.F. PETRIE	STATISTICAL ANALYSIS COMPUTER PROGRAM	DATE 12/31/68
TITLE "LIMIT", REJECT ANALYSIS--PLOTS HISTOGRAM, SUGGESTS TEST LIMITS.		G.E. CLASS II
		GOVT. CLASS NONE
REPRODUCIBLE COPY FILED AT AUDIO PRODUCTS DEPT., DECATUR, ILLINOIS		NO. PAGES 15

SUMMARY

PURPOSE:

1. ESTIMATE PRACTICAL TEST LIMITS FROM SAMPLE MEASUREMENTS DURING PILOT RUNS.
2. ESTIMATE VENDOR REJECT RATE DUE TO SORTING TO SPECIFIED LIMITS AND DETERMINE POTENTIAL IMPROVEMENT DUE TO CHANGING LIMITS.
3. MAKE ENGINEERING, MANUFACTURING, OR VENDOR FACE FACTS ON PRODUCT QUALITY DURING SAMPLE RUN, BEFORE PRODUCTION.

FEATURES:

1. USES RAW, UNSORTED INPUT DATA.
2. PLOTS HISTOGRAM, CALCULATES REJECTS, SUGGESTS LIMITS.
3. MANY GROUPS OF DATA MAY BE HANDLED IN SAME RUN.
4. HANDLES SKEWED DATA WITH REASONABLE ACCURACY.

LIMITATIONS:

HANDLES SKEWED DISTRIBUTIONS BY DIVIDING THEM INTO TWO "HALF GAUSSIAN" DISTRIBUTIONS AT THE PEAK OR MODE, YIELDING PESSIMISTIC PREDICTIONS ON HIGHLY SKEWED DATA.

LANGUAGE: XBASIC AND MK II BASIC

KEY WORDS

STATISTICAL ANALYSIS, HISTOGRAM, SKEWED, REJECT.

INFORMATION PREPARED FOR _____

TESTS MADE BY _____

AUTHOR ADELORE F. PETRIE

COMPONENT AUDIO PRODUCTS DEPT., DECATUR, ILLINOIS

APPROVED M West

JACK GANTT

VARIABILITY OF THE VARIABILITY
Probability Plot Methods of Study

Normal probability plotting has been extremely useful in the analysis of data of various kinds particularily the non-normal distributions that one encounters in actual factory situations. The use of a probability plot of "contrasts" to analyze designed two level experiments by Daniel[1] suggested to us that the method might logically be used in the analysis of process variability. We had always used either $\bar{R}$ or $\tilde{R}$ to estimate the inherent (short time) process variability (capability) not only for process control purposes but for process analysis as well. Now it seemed that the range of two plotted on a suitable probability paper might improve our ability to study the variability of process variability. It was anticipated that this might provide advantages similar to these obtained by the use of normal probability paper in studying process variability.

This investigation led to the use of "half-normal" probability paper and the delta plot (difference of two plotted on normal probability paper). To understand these two methods we need to recognize that the difference (keep the sign) between consecutive values from a normal distribution will also be a normal distribution. If the process is stable (in statistical control) the expected peak or average of the distribution is zero, with half the values plus and half minus. Hence a plot on normal probability paper should plot as a straight line. The variability of delta (difference of two) is related to the parent distribution variability as follows:

$$\sigma_\Delta = \sqrt{\sigma_x^2 + \sigma_x^2} = \sigma_x\sqrt{2}$$

$$\text{or} \quad \sigma_x = \frac{\sigma_\Delta}{\sqrt{2}} = .707\,\sigma_\Delta$$

Therefore it is a simple matter to convert the estimated variability of delta to an estimate of the variability of the process (parent distribution). If the delta plot was made from the difference of consecutive values in their order of production, then the estimated variability does not include the variability associated with process drifts or other time related effects, except as reflected in consecutive values. If the process under study is stable, both the probability plot of the individual values and the delta plot should be straight lines and the results that we get from this analysis would agree quite well with the conventional $\bar{X}$, σ & $\bar{R}$ estimates.

1. Cuthbert Daniel, "Use of Half Normal Plots in Interpreting Factorial Two-Level Experiments", Technometrics Volume I Number 4 November 1959.

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ATL RELIABILITY MEMO 35

INTRODUCTION TO RELIABILITY

by

Paul F. Albrecht, ATL Reliability

May 5, 1965

1. Need for Reliability

Every material device is subject to failure. Some things "hardly ever fail", such as bridges and aircraft structures. But even these devices can - and sometimes do - fail. Other devices fail "quite frequently", such as TV sets and automobiles. Still other devices fall between these two extremes, such as power transformers and turbine generators.

The fact that all material devices are subject to failure gives rise to the field of RELIABILITY. However, it is not simply the existence of failures which is responsible for the inception and growth of reliability. Material failures have always existed, but "reliability" as a distinct field is relatively new - less than 15 years old.

Equipment capabilities and performance levels have increased enormously in the past 15 years, but only at the expense of a corresponding increase in equipment complexity levels. As complexity increases, the frequency of failure likewise tends to increase. Eventually, the point is reached where the equipment is "down for repairs" most of the time. It was this situation which the Defense Department found in the late 1940's. That is, "failures" had become an obstacle to further state-of-the-art advances.

Concurrently with the increase in failure frequency due to increased complexity, an increase in failure cost occurred with the advent of the missile age. A single part failure in a large rocket would destroy several million dollars worth of equipment. In fact, reliability can trace its origin to the German V-1 rocket development at Peenemunde during World War II.

It is these two factors - increased failure frequency and increased failure cost - which are primarily responsible for the development and rapid growth of reliability as a distinct technology.

A Paper to be Presented at the SAE-ASME-AIAA Reliability and Maintainability Conference - 1964 Tri-Society Conference - June 29 thru July 1, 1964 in Washington, D. C.

DM 64-49

RELIABILITY ANALYSIS AND PREDICTION FOR TURBOJET ENGINES

RESULTS VS. NEEDS

February 7, 1964
(Revised)

D. D. Freberg and R. B. Spector

Reliability Engineering Operation
Large Jet Engine Department
General Electric Company
Cincinnati 15, Ohio

ABSTRACT

The Reliability Design Review is an effective tool in assisting designers towards achieving higher levels of Reliability early in the program. The Designer in the end is solely responsible for the Reliability achievement of his component. In this context Reliability activities of the sort described in this paper are a service to the Design Engineer in achieving his goals. Three Reliability prediction techniques and typical examples of the achieved results of each are described:

1. Controls and accessories Reliability Design Review practices and results of the 1959-60 Era.

2. Mechanization of the routine aspects of the Reliability Design Review procedure.

3. Probabilistic approach to failure rate estimation of basic engine structural parts.

SIMULATION METHOD APPLIED TO RELIABILITY ANALYSIS OF TURBOJET ENGINE COMPONENTS OPERATING IN AIRLINE SERVICE

R.S. Dorsey and H.A. Truscott
Aircraft Engine Group
General Electric Company
Evendale, Ohio
Dial Comm 8*332-4205
June 10, 1969

ABSTRACT

A brief description of a computer program generated to assess the reliability of a turbojet engine compressor disk is given. System simulation and Monte Carlo techniques are methods used in the program. The effects and interactions of Airline maintenance policy and component and engine design parameters are investigated. Results and discussion of a sample problem is given.

INTRODUCTION

Designers of turbojet engine components are seeking realistic answers to vital questions about the reliability of their components when they are exposed to airline service. Some of these questions are:

- What is the probability of component failure?
- When, in calendar time, will a failure occur?
- What effect do factors such as frequency of inspection, inspection capability, unscheduled engine removal rate, monthly utilization, maintenance policy, etc. have on these answers?

The designers must have new tools to generate meaningful answers to this set of complex questions. The answers require several random and deterministic variables. His normal stress/strain-load analysis technique is inadequate for complete answers. Simulation of the real-world process appears to be the approach most likely to achieve realistic answers.

This report describes a computer program that simulates the flow of components through an airline service operational system. Monte Carlo technique is used to simulate the occurrence of the random events in the system and to obtain distributions that provide clues to the statistical behavior of the system. The simulation utilizes IBM's General Purpose System Simulator (GPSS) II language [1,2].

represented by the largest percentage of tests having the smallest per cent range, other factors being equal. It can be seen that the ASA method shows 75% of the tests yielding data with less than 4.5% range, while the IEC method shows 75% of the tests yielding data with less than 6.5% range. Figs. 3 and 4 show similar results for fog-type suspensions, and all suspensions, respectively. The 75% level of test frequency for fog-types shows 7% voltage range for the ASA method and a 10% voltage range for the IEC method. For all suspensions, the 75% level shows 5 and 7% ranges, respectively, for the ASA and IEC methods. If a range of 5% is desired for all suspensions (Fig. 4) the IEC method will meet this requirement 45% of the time, the ASA method 78%.

Strings of nine of the conventional suspension insulators were also tested using the compromise test method and the results are as shown in Table II.

APPARATUS INSULATORS, CAP AND PIN TYPE FOR USE ABOVE 69 KV

Cap and pin type insulators for use above 69 kv were tested in stacks of 2, 4, 6, and 8 units. Both the IEC and ASA test methods yielded almost identical results (Fig. 5), and both show tendencies of proportionality with respect to arcing distance. Even more so than for suspension insulators, these apparatus insulators have much higher per cent voltage range on each specimen with the IEC test method than with the ASA test method as shown on Fig. 6. For 75% of the tests the IEC method indicated a 9% range, or almost twice the 5% range for the ASA test method. Curves have also been plotted on Fig. 7 to show how the two test methods result in a total variation of all arcs on the four different insulator combinations. Each individual flashover value has been expressed as a percentage of the average of all flashovers on each type of insulator and all of the data can be consolidated on single curves for each test method. These cumulative probability curves will give an indication of the variability to be expected in performing a wet test. The 100% voltage point on the abscissa represents the average flashover value, and, as shown, it would be expected that this average would occur at the median of the number of individual arcs.

The compromise proposal of test method was used to test several stacks of four high of the cap and pin apparatus insulators. Flashover values were obtained which were identical to those obtained with the ASA and IEC test methods (Table III).

APPARATUS INSULATORS, CAP AND PIN TYPE FOR USE BELOW 69 KV

The cap and pin type apparatus insulators, below 69 kv, showed essentially equal performance when tested under either of the two test methods (Fig. 8). A lower mean IEC value of approximately 7% was obtained for the 15 kv insulator, but the remainder of the sizes which were tested yielded practically identical results with either method. No difference existed in the variation in test voltages either on individual specimens or overall.

APPARATUS INSULATORS, POST TYPE, FOR USE BELOW 69 KV

Substantial disagreement between the ASA and IEC test methods is evident in the results obtained on post type insulators below 69 kv. As shown in Fig. 9, the results are very consistent for each method and show good indications of the flashover voltage being proportional to arcing distance. But, the IEC results are approximately 10% lower overall than the ASA results with specific mean values differing by 4 to 19%. This trend is very indicative of the IEC test method being quite incompatible with this type of insulator if the present test voltage levels are to be maintained. As with the cap and pin insulators, the post type insulators yield very consistent data with approximately equal, and quite small, variations in the flashover voltages from arc to arc.

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Schenectady, N.Y.

HIGH DENSITY, CONDUCTING MIST TEST FOR INSULATOR EVALUATION

by

J. M. Atkins and R. L. Gingrich
Physical Chemistry Laboratory

Report No. 71-C-050 January 1971

TECHNICAL INFORMATION SERIES

CLASS 1

PACIFIC GAS & ELECTRIC COMPANY
MOSS LANDING Contamination Test Program

NATURAL FOG

Report Prepared By

R. L. Thompson

ELECTRIC UTILITY ENGINEERING OPERATION

A-C TRANSMISSION ENGINEERING SECTION

AND

HIGH VOLTAGE LABORATORY

November 30, 1965

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SCHENECTADY, NEW YORK

TABLES
FIGURES
APPENDIX I
APPENDIX II
APPENDIX III

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TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT	NO.
F. S. Nichols	Hydrated Alumina and common dehydration	70-MATL-201
		DATE 6/29/70
TITLE		GE CLASS II
Drying and Dehydration of Hydrated Alumina		NO. PAGES 25
ORIGINATING COMPONENT	Chemical and Processes Section	

The drying and dehydration of hydrated alumina has been investigated using thermal analysis techniques. In spite of literature references claiming loss of combined water at low temperature, drying of hydrated alumina is not a critical operation. There was no significant loss of combined water after drying for periods up to 14 days at 125°C or one day at 150°C in a circulating air oven. Even after one week at 150°C the combined water was 34% against a theoretical 34.6%.

KEY WORDS
Hydrated alumina, dehydration, epoxy

INFORMATION PREPARED FOR RDT, IPD, DPED, PT

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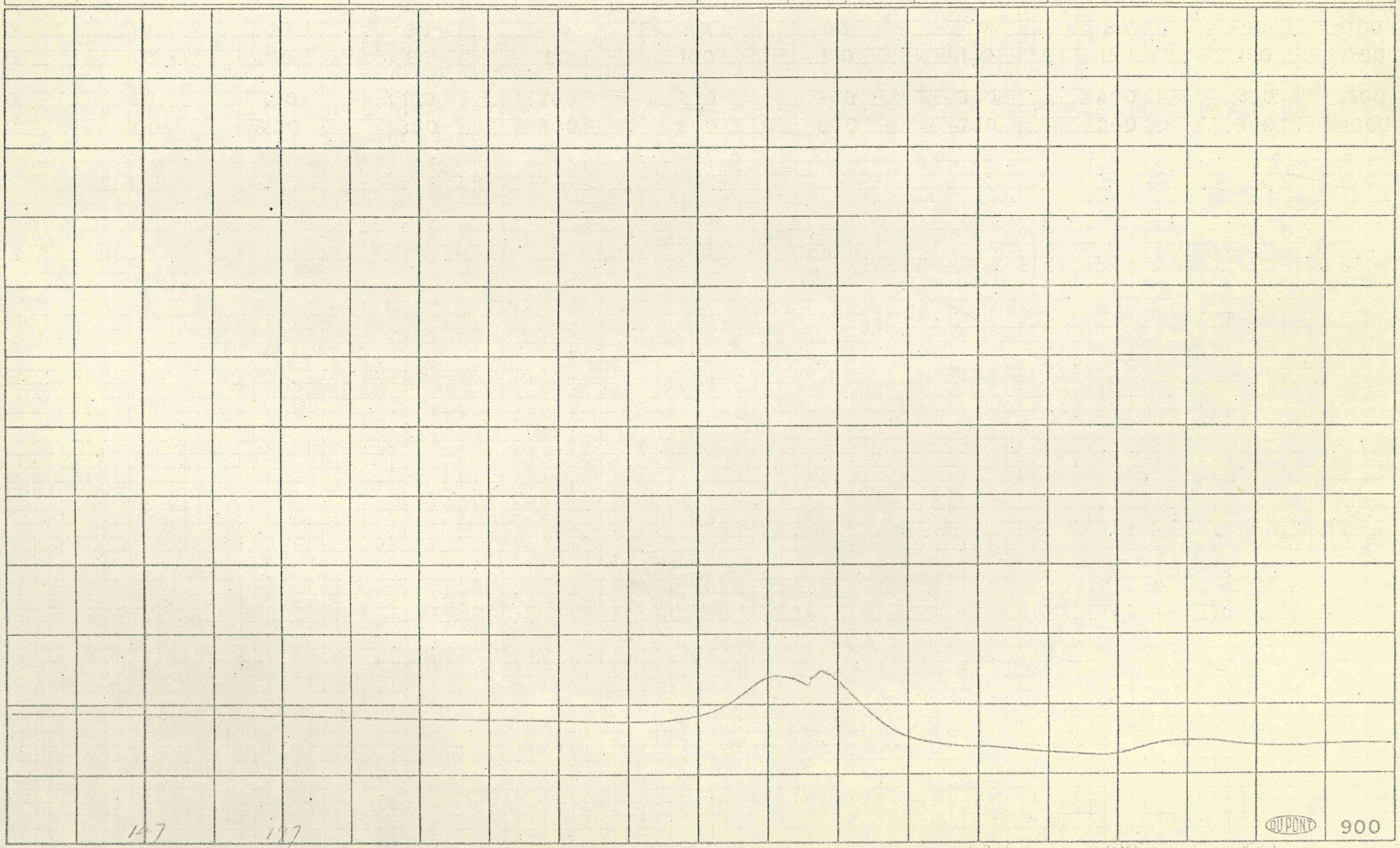
SAMPLE: ZC9804 NO FILLER	SIZE 0.00404 gms	ATM. N_2 6LPH MM	RUN NO. 1
	REF. Empty pan	T / ΔT	DATE APR 8, 1970
	PROG. MODE D.S.C. HEAT	SCALE 50 °C/IN. / 10 °C/IN.	OPERATOR [illegible]
ORIGIN:	RATE 15* °C/MIN, START 98 °C	SHIFT -2 IN. / IN.	BASE LINE SLOPE



*ACTUAL 15°C/MIN

T, °C (CHROMEL: ALUMEL)*

FIG. 9

SAMPLE: RUN NO.:

*SEE INSTRUCTION MANUAL FOR SCALE CORRECTION

INTRODUCTION

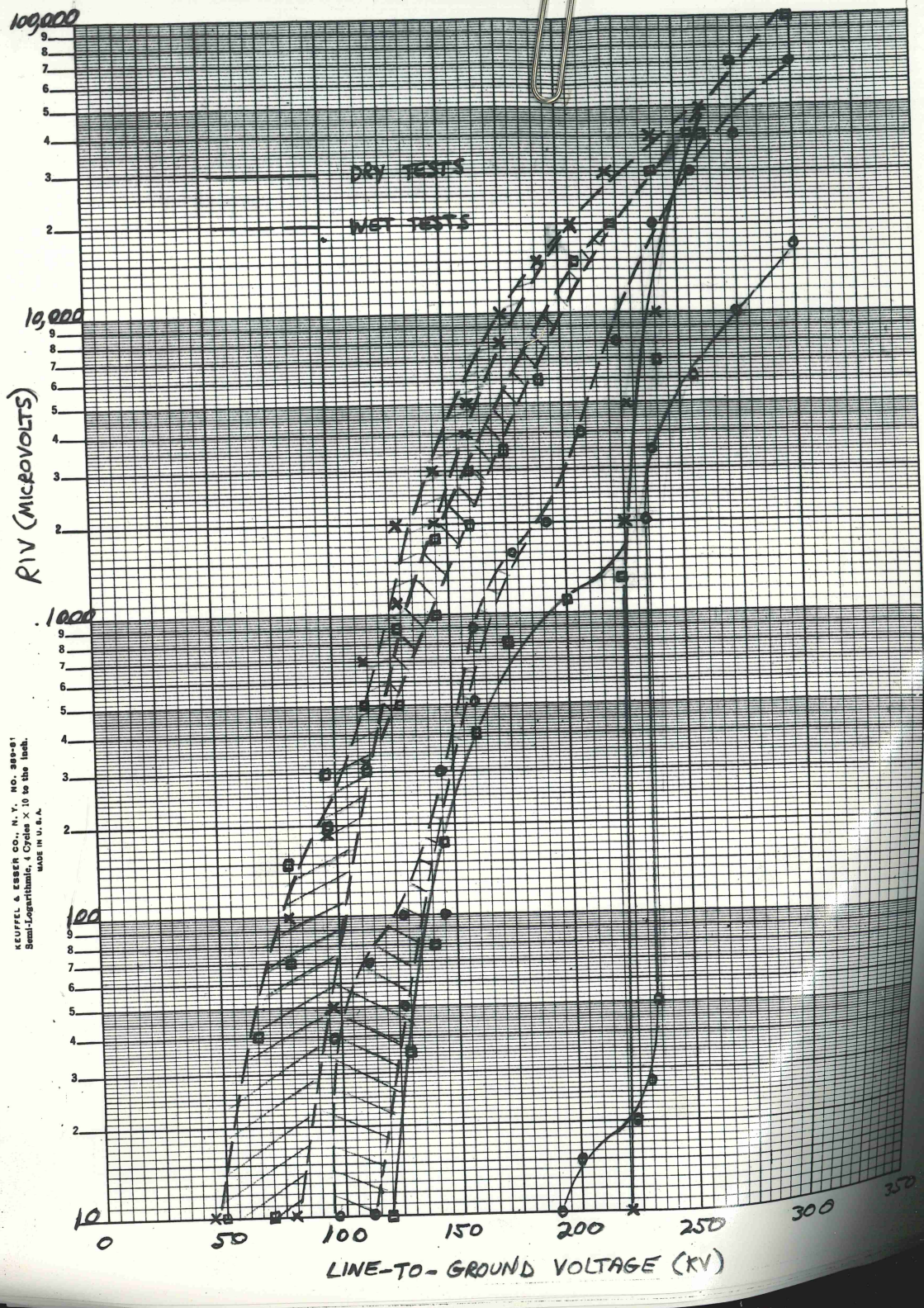
Wet flashover and wet withstand tests provide a necessary ~~measure~~ means to evaluate the electrical characteristics ~~of the characteristic to be used in the evaluation~~ of many types of high voltage equipment used on transmission and distribution lines and in substations. The American Standard for wet tests, ASA-C77.1-1943, was developed in order to establish a general standard method for tests that could be performed in the laboratory ~~which in turn could be~~ and related to levels of acceptable performance in the field. It was intended that this test embody ~~conditions which are like~~ an environment similar to that ~~those~~ encountered in the field but yet the test was to be one ~~in which only those elements over which~~ with reasonable control ~~can be exercised are specified~~ over specified elements. A reasonable degree of reproducibility was paramount.

The present American Standard has fulfilled these requirements and the practice of the standard has established specific wet flashover and withstand voltages.

Europe has similarly established a standard, each country having slightly different variations. ~~All these are quite different from the American standard.~~ The European standard specifies a water resistivity of 10,000 ohms per centimeter cube (3930 ohms per inch cube) and a rate of precipitation of three millimeters per minute (0.118 inches per minute) as contrasted to the American standard which specifies a water resistivity of 7,000 ohms per inch cube and a rate of precipitation of 0.2 inches per minute.

It is desirable that an international standard be established which could be used both in Europe and in America. One proposal advanced by the International Electrotechnical Commission (IEC) has been the adoption of the present European standard. In considering such a proposal, it is necessary to investigate the parameters which differ between the proposed European standard and the American standard. A preliminary investigation ~~reported in a paper (58-27) which presented a treatment of some of the aforementioned variables.~~ using the American standard as a base-line, presented a comparison of the effects of water resistivity and rate of precipitation. These ~~variables~~ factors were investigated one at a time, that is, the IEC water resistivity was used, but the ASA rate of precipitation

FIG. 3


Reduce to ½
100,000
10,000
1,000
100
10
DRY TESTS
WET TESTS
RIV (MICROVOLTS)
0
50
100
150
200
250
300
350
LINE-TO-GROUND VOLTAGE (KV)
KEUFFEL & ESSER CO., N.Y. NO. 359-81
Semi-Logarithmic, 4 Cycles × 10 to the Inch.
MADE IN U.S.A.

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A COMPARISON OF EUROPEAN AND AMERICAN WET FLASHOVER TEST METHODS

Bruce E. Kingsbury

INTRODUCTION

Wet flashover and wet withstand tests provide a necessary means to evaluate the electrical characteristics of many types of high voltage equipment used on transmission and distribution lines and in substations. The American Standard for wet tests, ASA-C77.1-1943, was developed in order to establish a general standard method for tests that could be performed in the laboratory and related to levels of acceptable performance in the field. It was intended that this test embody an environment similar to that encountered in the field but yet the test was to be one with reasonable control over specified elements. A reasonable degree of reproducibility was paramount.

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It is desirable that an international standard be established which could be used both in Europe and in America. One proposal advanced by the International Electrotechnical Commission (IEC) has been the adoption of the present European ~~standard~~. In considering such a proposal, it is necessary to investigate the parameters which differ between the proposed European standard and the American standard. A preliminary investigation, using the American standard as a base-line, presented a comparison of the effects of water resistivity and rate of precipitation. These factors were investigated one at a time, that is, the IEC water resistivity was used, but, the ASA rate of precipitation was maintained. Then, the procedure was reversed with the IEC rate of precipitation used, but, the ASA water resistivity was maintained.

In the present investigation, the combined effect of changing water resistivity and rate of precipitation was measured on suspension, pin-type, and apparatus insulators. Thus the work of the preceding paper has been extended, but, there still remains a need for similar data on other electrical apparatus.

METHOD OF TEST

The American standard practices were followed throughout in this investigation except for the water resistivity and rate of precipitation. The tests, for both IEC and ASA methods, were conducted using the rain angle, nozzles, and pre-wetting techniques as specified by ASA.

Various voltage classes as well as different types of geometrically-shaped insulators were used. Suspension insulators were tested in strings of 1, 3, 5, 6, 7, 8, 9, 10, 12, 15, and 18 units using both conventional and fog-type units. One low voltage pin-type insulator and one high voltage pin-type insulator were tested. Apparatus insulators comprised the remainder of the specimens which were investigated. Insulators designed for operation at 15 kv, 23 kv, 34.5 kv, and 69 kv of both the cap and pin and post-type construction were tested. Above 69 kv, only apparatus insulators of the cap and pin type were tested in stacks of 2, 4, 6, and 8 units.

Baltimore, January 9, 1956.

CC: Mr. C. H. Linder - NEW YORK

To Those Attending the
High Voltage Conference.

Gentlemen:

At the November 22nd High Voltage Conference, I was asked to submit brief reports on the subjects of "Electrical Breakdown", "Withstand Tests", Altitude Derating Factors", "Leakage Distance" and "Clearance Distance". I am attaching copies of these reports.

It is needless to say none of these reports are complete; in an inclusive sense each could be made a very extensive paper in itself. What we have tried to do is to outline very briefly what I believe to be the major knowns and unknowns in the field. We have deliberately avoided a discussion of some of the conventional variables, such as the difference between I.E.C. and American test practices, and also the conventionalized withstand test levels which have been established by the various product sections of NEMA.

In the latter case we have attached to the report on "Withstand Values" a curve which shows the general trend in standardized product withstand levels. The shaded areas of this curve indicate those zones where there is a difference between the withstand levels specified for different types of product. In some cases there are probably very good reasons for these differences, and it was not my thought that you would use these meetings at this stage in their development to try to iron out such product variables.

Very truly yours,

H. A. Frey

Manager - Engineering
Locke Department.

HAFrey/LP

Conference Paper

FIRST 500 kv A-C TRANSMISSION LINE DESIGNS FOR THE BONNEVILLE POWER ADMINISTRATION'S GRID

A. A. Osipovich
Senior Member IEEE

M. G. Poland
Senior Member IEEE

Bonneville Power Administration
U. S. Department of the Interior
Portland, Oregon

A paper scheduled by the IEEE Transmission and Distribution Committee for presentation at the IEEE Summer General Meeting, Toronto, Ontario, Canada, June 16-21, 1963.

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Paper No. CP

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Transactions Paper

(Reviewed and Accepted for Publication)

VOLTAGE GRADIENTS ON HIGH VOLTAGE TRANSMISSION LINES

G. E. Adams
Associate Member AIEE
General Electric Co.
Schenectady, N. Y.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31-February 4, 1955. Manuscript submitted October 21, 1954; made available for printing November 10, 1954.

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Paper No.
55-22

Discussion in Duplicate Due February 16, 1955.

Technical Paper
TP-2000 B

A REVIEW OF INSULATION AND CLEARANCE PRACTICES of HIGH VOLTAGE SUBSTATIONS

by

E. A. Williams

A paper presented to the joint meeting of the Electrical Equipment and Transmission and Distribution Committees, Pennsylvania Electric Association, Reading, Pa., October 8-9, 1953.

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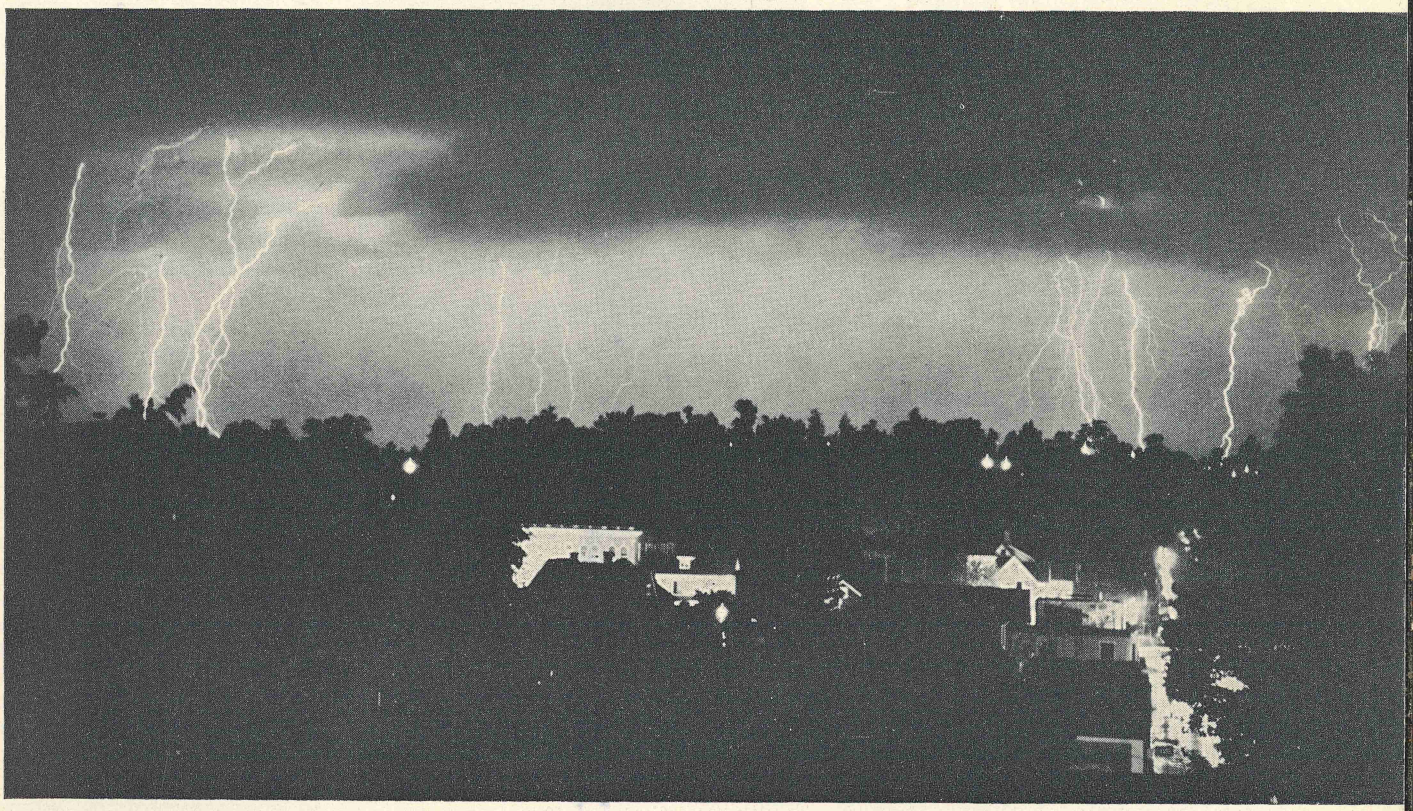
MODERN CONCEPTS OF LIGHTNING PROTECTION FOR TRANSMISSION AND DISTRIBUTION SYSTEMS



BY

H. M. TOWNE

GENERAL ELECTRIC COMPANY

PITTSFIELD, MASS.

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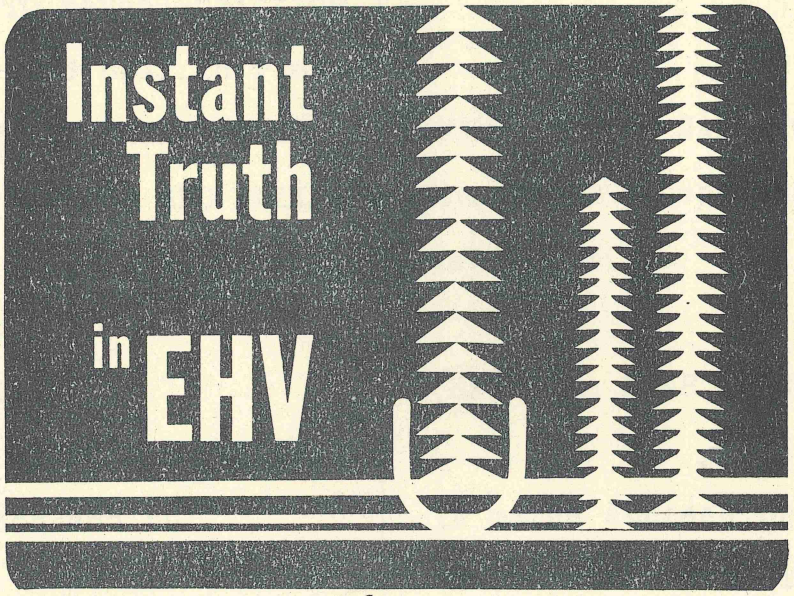
THIRD DRAFT

January 29, 1963

A motion picture script



prepared for

THE INSULATOR DEPARTMENT

Baltimore, Maryland

Client Representatives:

F. R. McVicker
M. Stack

Approved for production by:

Name _____
Date _____

Prepared by:

J. B. Updyke
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Schenectady, New York

PRODUCT REFERENCE FILE

METIFOR—A Statistical Method for Insulation Design of EHV Lines

J. G. Anderson, *Senior Member IEEE* *L. O. Barthold*, *Senior Member IEEE*

Summary: Using sequential hourly weather data available on punched cards from the United States Weather Bureau, digital weather models of the future climate in the vicinity of a proposed transmission line can be constructed. These models permit statistical forecasts of line performance. Application of the technique to line insulation strength is demonstrated. Performance can be predicted on an over-all basis, or can be studied at specific times of the day, or during fog periods or thunderstorms. Optimizing routines are presented that optimize or permit balancing of flashover characteristics, and forecast performance as a function of line investment.

Paper **64-37**, recommended by the IEEE Transmission and Distribution Committee and approved by the IEEE Technical Operations Committee for presentation at the IEEE Winter Power Meeting, New York, N. Y., February 2–7, 1964. Manuscript submitted November 6, 1963; made available for printing December 11, 1963.

J. G. Anderson is with the General Electric Company in Pittsfield, Mass., and L. O. Barthold is with the same company in Schenectady, N. Y.

The authors gratefully acknowledge the contributions of their many associates whose research work, discussions, and direct assistance were of immense value. Of particular mention are the discussions and suggestions of H. C. S. Thom and G. J. Bulgarelli of the United States Weather Bureau; G. K. Carter, P. M. Cabral, and M. S. Dyrkacz for their programming of much of the work; D. D. MacCarthy and E. M. Hunter for their encouragement and guidance; A. F. Rohlfs, F. J. Turner, and J. R. Meador for the flashover data to make METIFOR a realistic program; and the many other coworkers who contributed in numerous ways.

The recent upsurge in the use of extra-high-voltage (EHV) transmission has brought with it several new technical and economic attitudes. Both design philosophies and techniques have been reappraised in the light of the increased incentives for cost control and the greater opportunities for precision afforded by recent progress in industry research.

Any discussion of transmission-line design philosophy resolves itself into the consideration of three arguments: (1) the electrical and meteorological *environment* to which the line will be subjected, (2) the *criteria* assigned to its operating performance, and (3) the intrinsic design *dimensions* proposed to fulfill the criteria established.

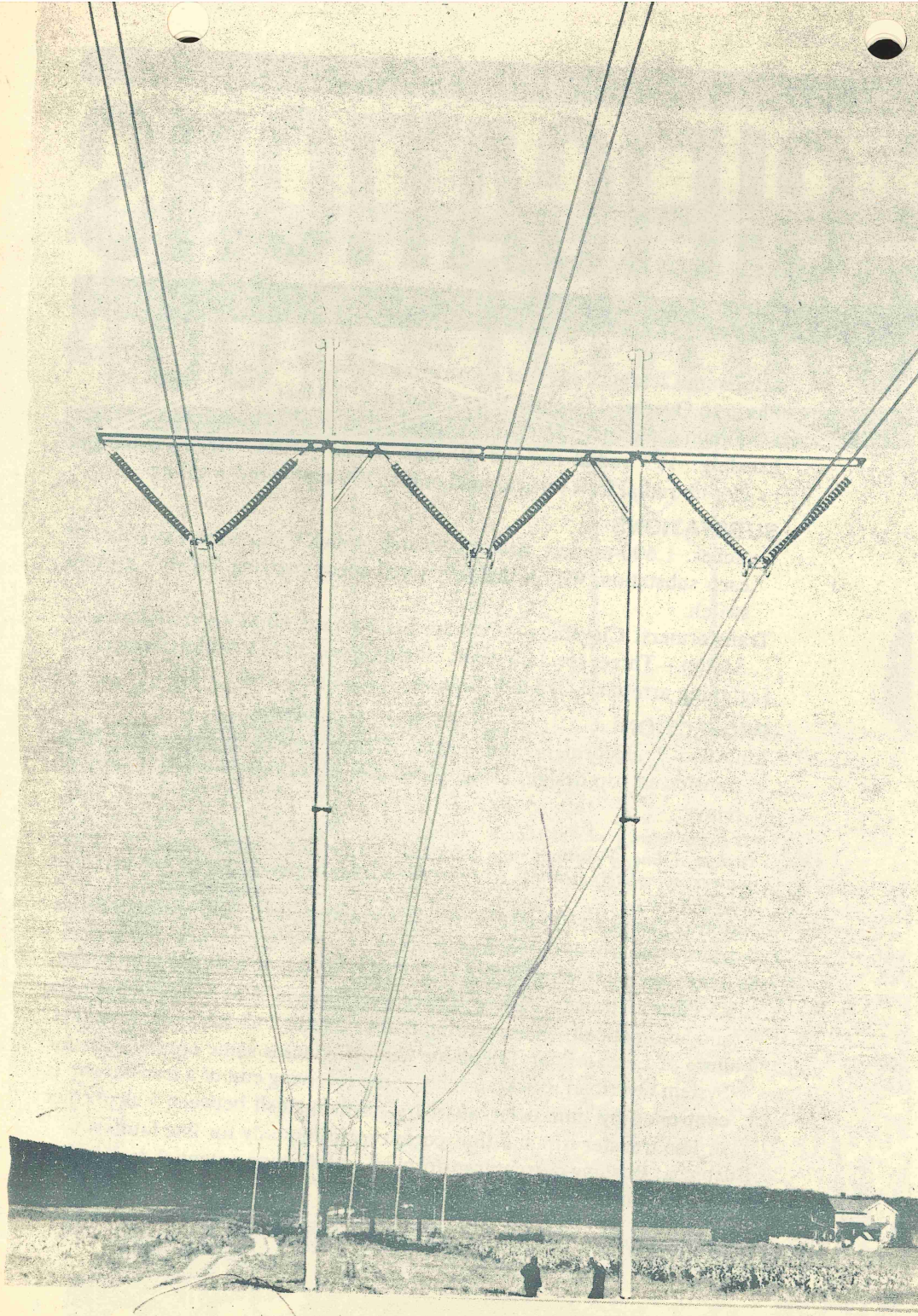
While the discussion here is confined to electric systems, and more particularly to transmission lines themselves, the stated arguments are found to be inherent in practically any design problem.

Design criteria may be further subdivided into cases where noncompliance is catastrophic as opposed to those in which it is not. A bridge must never collapse, but its pavement need

EHV DC TRANSMISSION

BY E. M. HUNTER, G. D. BREUER AND C. C. HERSKIND
THE GENERAL ELECTRIC COMPANY

Reprinted from TRANSMISSION & DISTRIBUTION, September, 1965



460 KV = EHV

The Pennsylvania Electric Company has built the nation's first operating 460-KV power transmission line as part of its continuing program to develop and use the latest technology to provide customers with dependable service.

Penelec also regards the unusual engineering and construction work which has gone into this project as a contribution to the "art" of EHV transmission. The ultra-severe demands, of 460-KV service require:

WIRES—thick as a man's wrist

PORCELAIN INSULATORS—15 feet long

CROSS-ARMS—big as a barn beam

STRUCTURES—up to 130 feet high

TRANSFORMER—holding in its tank all of the oil carried by the largest railroad tank car

SWITCH BLADES—20 feet long, 4 inches in diameter

It took 260 working days to erect this transmission line. It required not only new hardware, but new construction methods as well. Despite this, it is a practical line, with pure EHV research and development a by-product.

During the next two years, intensive tests will be made to obtain a clearer understanding of stresses and strains, of behavior and of effectiveness of design. And, just as important, during that period the line will be performing the function for which Penelec exists—serving its customers.

Field tests being performed along the line after [illegible]

PRODUCT REFERENCE FILE

THE TEINOGRAPH - A NEW HIGH-VOLTAGE SURGE RECORDER

J. G. Anderson
Member - AIEE

R. U. Giacomoni
Associate Member - AIEE

Both of:
General Electric Co.
Pittsfield, Mass.

To be presented at the AIEE Middle Eastern District Meeting,
Baltimore, Md., May 19, 1959

American Gas and Electric Company 500-Kv Test Project

Corona, Radio Influence, and Economics on High Voltage Transmission Lines and AG&E Co. 315-Kv System

Reprint of
Six Technical Papers including discussions presented
before the AIEE 1950–51 on the above subject

Group Participating in the Project

American Gas and Electric Service Corporation (Sponsor)
Aluminum Company of America
American Bridge Company
Anaconda Wire and Cable Company
General Cable Corporation
General Electric Company
Locke Insulator Corporation
Ohio Brass Company
Westinghouse Electric Corporation

The American Institute of Electrical Engineers

Transactions Paper

(Reviewed and Accepted for Publication)

THE CALCULATION OF THE RADIO INTERFERENCE LEVEL OF TRANSMISSION LINES CAUSED BY CORONA DISCHARGES

G. E. Adams
Associate Member AIEE
General Electric Company
Schenectady, N. Y.

A paper recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30-February 3, 1956. Manuscript submitted October 20, 1955; made available for printing December 20, 1955.

Price: 40¢ To Members
80¢ To Nonmembers

(5¢ per copy additional if first class mailing desired)

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American Institute of Electrical Engineers
33 West 39th Street, New York 18, N. Y.
Litho in USA

Paper No.
56-222

Discussion in Duplicate Due February 15, 1956.

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
CORPORATE RESEARCH
AND DEVELOPMENT

EUROPEAN TECHNOLOGY REPORT

EUROPEAN OFFICE
Lowenstrasse 29
Ch 8001 Zurich,Switzerland

For Cited References: Technical Information Exchange, Bldg. 5, Rm. 221, Schenectady, N. Y. • Dial Comm 8-235-5068

72T7

February 21, 1972

HIGH VOLTAGE TECHNOLOGY

The 1972 International Symposium on High Voltage Technology will take place in Munich, W.Germany, on March 9-14, 1972. It is being organized by VDE (German Association of Electrical Engineers) and the IEEE Power Engineering Society. Scientific Chairman is Professor Hans Prinz of the High Voltage Institute, Technical University, Arcisstr.21, D-8 Munich 2, W.Germany.

The conference program is outlined below and a list of the 93 papers to be presented is also given. These papers have been compiled in a conference volume which is now available at the Technical Information Exchange Office of Corporate R&D, Bldg. 5, Room 221, P.O.Box 43, Schenectady, NY. When ordering copies of any of the papers, please indicate exact titles and numbers of the papers as well as the number of this report: 72T7.

A.M. Gurewitsch, Consultant
Applied Science and Technology - Europe
Zurich, Switzerland
AMG/mb

List of Papers to be Presented:

A. The Calculation of Electric Fields in High Voltage Devices

1. "Determination of Boundary Coordinates by means of Finite-Difference Methods" by K. Antolic, Micafil-Zurich, Switzerland

9. "The Electromagnetic Wave of the High Voltage Impulse" by H.Böcker, TU-Stuttgart

17. "Automatic Calculation of Electric Fields" by N.Flatabö et al., TU-Trondheim, Norway

23. "Safety Hazards beneath High Voltage Lines" by E.T.B.Gross, M.H.Hesse, Rensselaer Polytechnic, Troy, NY, USA

30. "Calculation of the Effectiveness of Shielding against Quasistatic Electric Fields" by G.Karady and N.Hyltén, Hydro-Quebec,Canada

36. "Potential Gradients on the Surface of Shielding Electrodes for Ultra-High Voltages" by J.Moeller et al., Messwandler-Bau GmbH, Bamberg, W.Germany

44. "Derivation of System Models Applying the Finite Element Method" by K.Reichert, BBC-Baden,SWitzerland

52. "Computation of Electric Fields: Recent Developments and Practical Applications" by M.F.Scott et al., Reyrolle Parsons Ltd., Hebburn, UK

59. "The Electric Field of Polycon Electrodes" by H.Singer, TU, Munich, W.Germany

67. "Calculation of Maximum Stress in Gas Insulated Bus-Bars" by T.Takuma et al., Central Research Institute of Electric Power Industry, Tokyo, Japan

73. "Field Strength Effects in Two-Dielectric Arrangements" by P.Weiss, TU, Munich,W.Germany

B. The Measurement of Electric Field Strength in High Voltage Devices

81. "Contribution to Electric Field Measurement Technique by means of Probes" by J.Aubry et al., Electricité de France, Paris

86. "Electrical Field in Long Rod-Rod Gaps" by G.Baldo, M.Rea, Padova University, Italy

CLASS 2 - FOR GENERAL ELECTRIC EMPLOYEES ONLY

Address special inquiries to A. M. Gurewitsch at the above Zurich Address, or Telephone 230095, cable GECATEL

Transactions Paper

(Reviewed and Accepted for Publication)

EFFECT OF BUNDLE-CONDUCTOR FIELD INFLUENCE

ON EHV TRANSMISSION LINE DESIGN

RECEIVED
JAN 17 1961
G. M. BOYD

R. W. Harmon
Member AIEE
The Ohio Brass Company
Barberton, Ohio

RECEIVED
JAN 17 1961
H. A. FREY

A paper recommended by the AIEE Transmission and Distribution Committee and approved by the AIEE Technical Operations Department for presentation at the AIEE Winter General Meeting, New York, N. Y., January 29-February 3, 1961. Manuscript submitted August 8, 1960; made available for printing December 2, 1960.

Price: $ .50 To Members
$1.00 To Nonmembers

(5¢ per copy additional if first class mailing desired)

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American Institute of Electrical Engineers
33 West 39th Street, New York 18, N. Y.
Litho in USA

Paper No.
61-171

Discussion in Duplicate Due February 17, 1961.

57-1077

Transactions Paper 57-1077

SUSPENSION INSULATOR FLASHOVER UNDER HIGH IMPULSE VOLTAGES

by B. E. Kingsbury

Closure by B. E. Kingsbury

The discussions which have been presented by Messrs. Concordia, Fritz and Rohlfs are greatly appreciated.

Mr. Fritz asks some questions which are beyond the scope of this paper and will require further work and study before their answers can be forthcoming. In those cases where long counterpoise systems are required because of poor ground resistances, the advantage of several microseconds delay in flashover for the shorter spaced insulators would provide definite protection in view of the long periods before alleviation of the stricken structure can be effected.

As Mr. Rohlfs points out, the correlation of this and the companion paper are good and the data should provide benefits for transmission design.

By plotting the flashover voltage versus arcing distance, a particular type of insulator can be evaluated under both standards. By using the ASA standard as the base line, it can then be readily determined whether or not there exists a difference between the two standards for any one particular voltage class, and, also, whether or not the trend of the results using the IEC method agrees with the base line as the tests progress upward through the voltage classes. It is logical to consider that the resulting curve of flashover voltage versus arcing distance, while fairly linear as determined by the American standard for most types of insulators, may not be coincidental for the IEC standards. It may not have the same slope, and may not even have the same semblance of linearity. In plotting these curves, only the mean of the average values of similar test specimens is shown. The average curve drawn through these points would depict the expected true performance as obtainable with the particular test standard. This average curve would then be used to determine whether or not a plausible comparison exists both between the two standards and between the ratings and the European standards. The mean values of specific insulators can then be examined as to how well they fit the overall picture.

In some cases it is apparent that certain types of insulators do not show the same general pattern as do the majority of others. This, then, might indicate one further point to be gained from this investigation; i.e., that some geometrical shapes, while designed to adequately meet existing ASA standards, react in an aggravated manner to different conditions of test. That is, they are super-sensitive to various atmospheric conditions and may not perform as expected.

The reliability of the wet test is dependent upon there being as small a variation as possible between the high and low values obtained, upon which the average value is predicated. It was noted that the IEC standards seemed to consistently yield results which were more erratic than those of the American standard. This erratic performance exists not only from specimen to specimen, but also, from arc to arc on the same specimen. Data have been plotted so as to develop frequency distribution curves showing the cumulative percentage of tests as a function of the flashover voltage range. The range for each test has been expressed as a percentage based upon the average of the particular test so that all of the data for each type of insulator can be consolidated and plotted together. Comparisons can be made between the two standards for the different types of insulators tested.

SUSPENSION INSULATORS

Both conventional and fog-type insulators were tested so that the effect of geometry could be determined. The flashover test values for conventional insulators obtained with both the ASA and IEC test methods, when plotted against arcing distance, appear to be linear. The test values shown for the IEC method have a greater variability than the ASA values but do not deviate by more than 8.5% from the average curve values.

The mean values of the IEC test method for fog-type insulators are generally higher than are those for the ASA test method (Fig. 2). An average curve can be readily drawn through the means of the ASA data, and, in comparing specific IEC test data points with ASA mean curve, it is found that as much as a 24.3% difference exists. Such large differences indicate that more data should be obtained, and, if a like differential is determined, then no valid correlation would seem to exist.

The range on individual tests for conventional insulators is shown by Fig. 3. The range between the minimum and maximum flashover voltage for each test specimen is expressed as a percentage based upon the average flashover voltage for that specimen, and all the data was then consolidated so that the frequency of occurrence of tests could be plotted as a function of the per cent range. The preferred test method would be

TECHNICAL REPORT NO. LK-904

PROGRESS REPORT OF AGING TESTS ON THE 20,000 lb. INSULATORS

Author:

R. Weller
Product Engineer

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GM Boyd
ES Wheeler
CD Croskey
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BE Kingsbury
RH Lester
WB Lounsbury
HM Williams

Approved:

R. H. Lester, Manager
Ceramic Insulator Engineering

INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
October 15, 1968

TECHNICAL REPORT NO. LK - 919

REPORT OF TESTS ON CAST ALUMINUM SUSPENSION CAP BY ALCOA

Author:

R. Weller
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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND

January 29, 1969

TECHNICAL REPORT LK-927

AGING TESTS ON INSULATORS HAVING TWO COATS OF ADIPRENE

Author:

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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
April 28, 1969

TR 8380

TECHNICAL REPORT NO. LK-917

EVALUATION AND TESTS ON THE CATALOG 40S298 FOG TYPE INSULATOR

Author:

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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
January 13, 1969

TECHNICAL REPORT LK-CR 201

HYDRAULIC TESTING OF NOs. 18290A - 40,000 lb. and 18380A - 50,000 lb. SUSPENSION SHELLS

AUTHOR:

C. D. Croskey
Manager-Ceramic Laboratory

APPROVED:

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E. S. Wheeler
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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MD.

August 6, 1968

TECHNICAL REPORT LK-881

EVALUATION AND TESTS ON NGK SUSPENSION CAT. 525MC, 18,000 LB. INSULATOR

Author:

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Approved:

J. M. Jesatko
Acting Manager-Product Engineering

Insulator Department Baltimore, Maryland June 12, 1968

TECHNICAL REPORT LK-879

EVALUATION AND TESTS ON THE LAPP CAT. 8200 INSULATOR 20,000 LB. ASA CLASS 52-3

Author:

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Insulator Department

Baltimore, Maryland

June 6, 1968

TECHNICAL REPORT LK-861-A
SUPPLEMENT NO. 1

EVALUATION AND TESTS ON THE OB CAT. 47310 SUSPENSION INSULATOR

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Insulator Department Baltimore, Maryland June 12, 1968

TECHNICAL REPORT LK-882

EVALUATION AND TESTS ON THE NGK CAT. DA-500 MQ 25,000 LB, SUSPENSION INSULATOR

Author:

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Acting Manager-Product Engineering

Insulator Department Baltimore, Maryland June 13, 1968

TECHNICAL REPORT LK-CR-209

STATUS OF RESEARCH ON STABILIZED GLAZED INSULATORS FOR USE IN CONTAMINATED AREAS

Author:

C. D. Croskey
Manager-Ceramic Laboratory

Approved:

E. S. Wheeler 2/26/69
E. S. Wheeler
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R Weller
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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
February 25, 1969

TECHNICAL REPORT NO. LK-923

TIME-LOAD TESTS ON NGK SUSPENSION INSULATORS

Author:

R. Weller
Product Engineer

Approved:

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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
February 25, 1969

TECHNICAL REPORT NO. LK-924

DEVELOPMENT OF A PEARLITIC MALLEABLE IRON CAP FOR 30,000 LB. INSULATOR

Author:

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Approval:

R. H. Lester, Manager
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INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
March 3, 1969

TECHNICAL REPORT LK-930

SOLID STATION POST INSULATORS

Author:

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INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
June 30, 1969

TECHNICAL REPORT LK-CR 212

FEASIBILITY STUDY --- CONDUCTIVE GLAZES
TIN-ANTIMONY OXIDE TYPES

Author:

C. D. Croskey, Manager
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Manager-Engineering

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INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
July 1, 1969

LK 932

RECORD OF TESTS NO. 24242

THERMAL ENDURANCE TESTS ON SUSPENSION INSULATORS FOR CONEMAUGH PROJECT

A. L. Libby
Product Engineer

R. Weller
Product Engineer

C. Bowen
Baltimore Gas & Electric Co.

R. H. Lester, Manager
Ceramic Insulator Engineering

INSULATOR DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
December 2, 1968

TI-104 (7-56)

GENERAL ELECTRIC
INSULATOR PRODUCTS DEPARTMENT
BALTIMORE, MARYLAND
RECORD OF TESTS

No. 24597
Date Oct 31, 1969
Page 1 of 6

Nature of Tests: RADIO INFLUENCE VOLTAGE AND CORONA OBSERVATION AT 60HZ ON DUAL CONDUCTOR SPACERS		Material
Refer to Data Sheet No. 24554	Test Req. No.	Dual Conductor Spacer

Copies to
Preformed Line Products Co.
Dept. of Water & Power, City of Los Angeles

I. GENERAL

The tests described below were performed in the High Voltage Laboratory, Insulator Products Department, General Electric Company on September 23, 1969 on 500Kv-AC rated two-conductor spacers.

II. CUSTOMER AND SPECIFICATIONS

These tests were made for the Preformed Line Products Company of Cleveland, Ohio. The tests were run to qualify conductor spacers for sale to The Department of Water and Power of the City of Los Angeles (abbreviated "LADWAP" on occasion) and specification No. 7248.

III. WITNESSES

The following persons, other than laboratory personnel, were present during all tests:

Mr. Tom Eistrat	Department of Water and Power, City of Los Angeles
Mr. Raymond J. Champa	Preformed Line Products Company
Mr. Mike Hathway	Preformed Line Products Company
Mr. Jim Jung	Preformed Line Products Company

IV. MATERIAL

The following material items were included in some or all of the tests performed:

1. Alcoa ACSR Conductor, 2050 MCM 76/19 Stranding, 1.700 inches outside diameter, with Alcan Aluminum fittings
2. Alcan All Aluminum Conductor, 2,500 MCM 91 strands, each 0.1657 inches in diameter, total outside diameter 1.823 inches with Alcan Aluminum fittings
3. Preformed Line Products Helical Spacer SU-MS-5462 (Dept. of Water & Power item #11-A)

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Signed AM

Approved

TECHNICAL REPORT NO. LK-937

LEAKAGE CURRENT MEASUREMENTS ON 15 KV AND 34 KV GEPOL® INSULATORS

Author:

Fred C. Vose

F. C. Vose, Manager
Polymer Insulator Engineering

Approved:

E S Wheeler 11/11/69

E. S. Wheeler
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M Tabor

INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
November 7, 1969

TECHNICAL REPORT NO. LK-941

AGING TESTS ON 40S360 GO6 INSULATOR

Author:

R. Weller
Product Engineer

Approved:

R. H. Lester, Manager
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RT Fleming
J Kelenfy
BE Kingsbury
RH Lester
AL Libby
HM Williams

INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
December 5, 1969

TECHNICAL REPORT NO. LK-939-DR

DESIGN TESTS ON THE CATALOG NO. 40S296 FOG TYPE INSULATOR

Author:

R. Weller
Product Engineer

Approved:

R. H. Lester, Manager
Ceramic Insulator Engineering

Distribution:

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RT Fleming
J Kelenfy
BE Kingsbury
RH Lester
AL Libby
HM Williams

INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
December 9, 1969

TECHNICAL REPORT NO. LK-938-DR

DESIGN TESTS ON CATALOG NO. 20S185 FOG TYPE INSULATOR

Author:

R. Weller
Product Engineer

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Approved:

R. H. Lester, Manager
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INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
November 19, 1969

TECHNICAL REPORT NO. LK-940-DR

DESIGN TESTS ON THE CATALOG 30S263 FOG TYPE INSULATOR

Author:

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RH Lester
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HM Williams

Approved:

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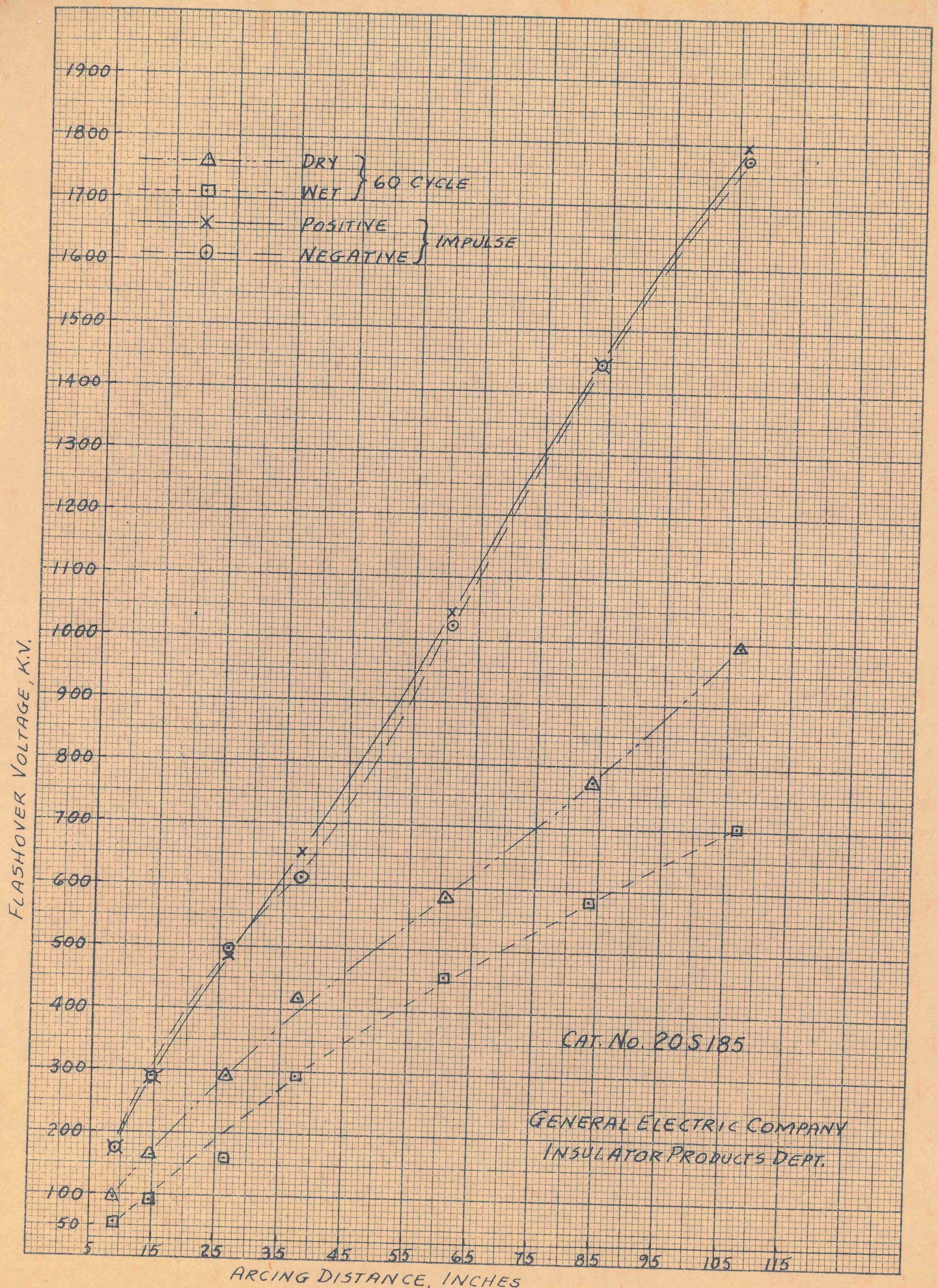
INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
November 18, 1969



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MADE IN U.S.A.
46 1327

TECHNICAL REPORT LK-936

THERMAL ENDURANCE TESTS ON SUSPENSION INSULATORS FOR PUBLIC SERVICE ELECTRIC AND GAS COMPANY

OCTOBER 27, 1969

A. L. Libby, Manager
High Voltage and Mechanical Laboratory

INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC CO. BALTIMORE, MARYLAND
November 5, 1969

TECHNICAL REPORT NO. LK-951-DR

INFLUENCE OF COATINGS ON THE AGING MECHANISM OF SUSPENSION INSULATORS

Author:

R. Weller
Product Engineer

Distribution:

ES Wheeler
CD Croskey
BE Kingsbury
RH Lester
AL Libby
HM Williams

Approval:

R. H. Lester, Manager
Ceramic Insulator Engineering

INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
June 22, 1970

TECHNICAL REPORT LK-936

THERMAL ENDURANCE TESTS ON SUSPENSION INSULATORS FOR PUBLIC SERVICE ELECTRIC AND GAS COMPANY

OCTOBER 27, 1969

A. L. Libby, Manager
High Voltage and Mechanical Laboratory

INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC CO. BALTIMORE, MARYLAND
November 5, 1969

TECHNICAL REPORT NO. LK-942-DR

DESIGN TESTS ON THE CATALOG 30S268 FOG TYPE INSULATOR

Author:

R. Weller
Product Engineer

Approved:

R. H. Lester, Manager
Ceramic Insulator Engineering

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December 16, 1969

TECHNICAL REPORT LK-CR-219

THE EFFECT OF THICK CEMENT ON THE M&E STRENGTH OF SUSPENSION INSULATORS WHEN STORED IN AIR AND IN VACUUM

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CHARACTERISTICS OF PCB POSTS

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July 28, 1971

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A-30 EXPERIMENTAL ALUMINA BODY LABORATORY PROGRAM PROGRESS REPORT #1

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INSULATOR PRODUCTS DEPARTMENT GENERAL ELECTRIC COMPANY BALTIMORE, MARYLAND
August 19, 1971

TECHNICAL REPORT LK-CR-221

REYNOLDS RC24-GF ALUMINA: SHOP TRIAL IN 304-3 and A-30 FORMULATIONS

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GENERAL ELECTRIC COMPANY
PROTECTIVE EQUIPMENT PRODUCTS DEPARTMENT BALTIMORE, MARYLAND

May 1, 1972

CALCULATION OF TRANSMISSION LINE LIGHTNING VOLTAGES BY FIELD CONCEPTS

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New York

District Paper Presented at
AIEE Northeastern District Meeting
Pittsfield, Massachusetts
May 2, 1957

DP 57-537

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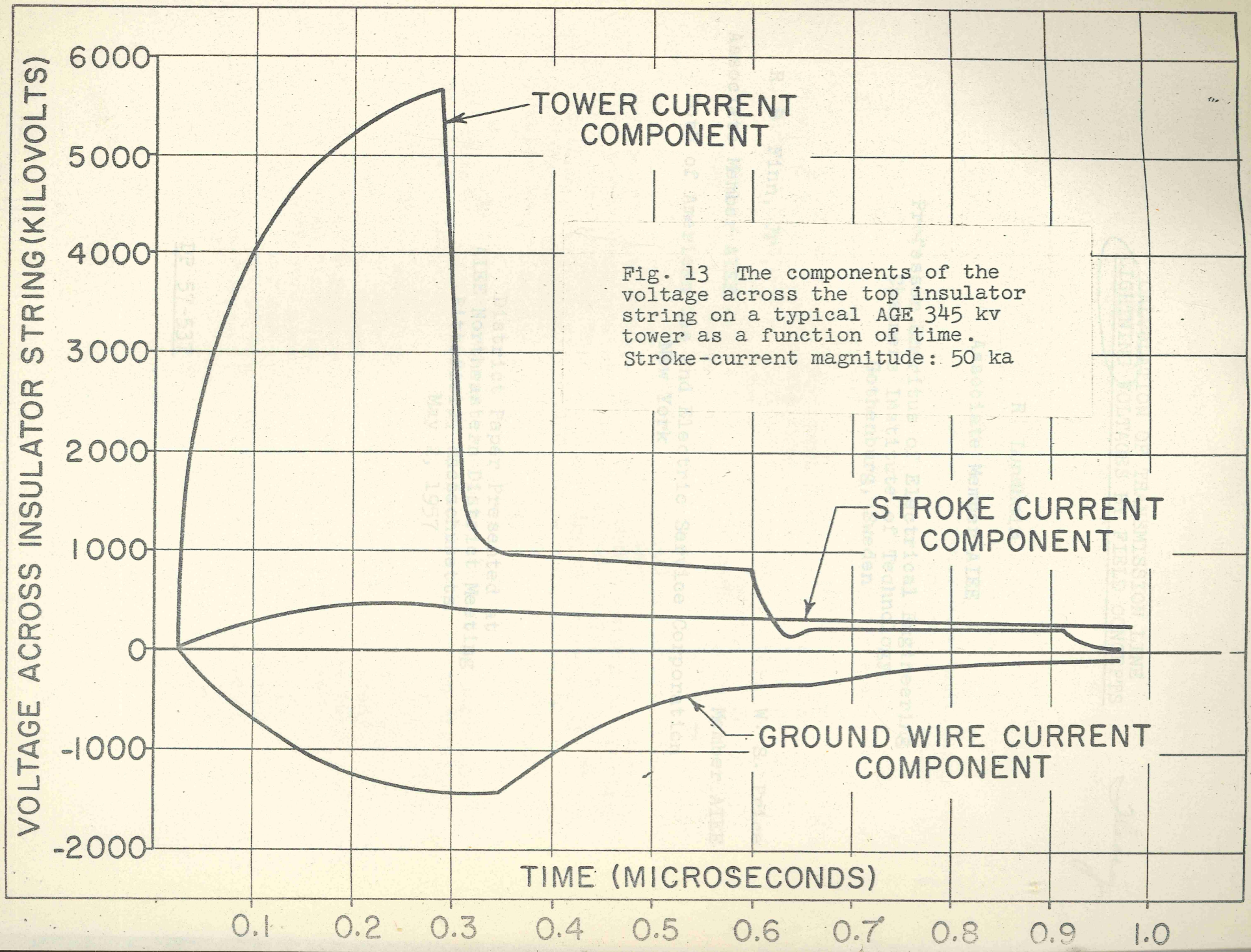

Fig. 13 The components of the voltage across the top insulator string on a typical AGE 345 kv tower as a function of time. Stroke-current magnitude: 50 ka

District Conference Paper

Lightning Theory

AN APPROXIMATE TRANSIENT SOLUTION OF THE TAPERED TRANSMISSION LINE

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A paper recommended by the AIEE North Eastern District Meeting Committee for the AIEE North Eastern District Meeting, Pittsfield, Mass., May 1-3, 1957. Manuscript submitted February 27, 1957; made available for printing March 13, 1957.

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57-548

Lightning Theory

FIELD STUDIES OF THE SURGE RESPONSE OF A 345 KV TRANSMISSION TOWER AND GROUND WIRE

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AIEE Northeastern District Meeting

Pittsfield, Mass. - May 1-3, 1957

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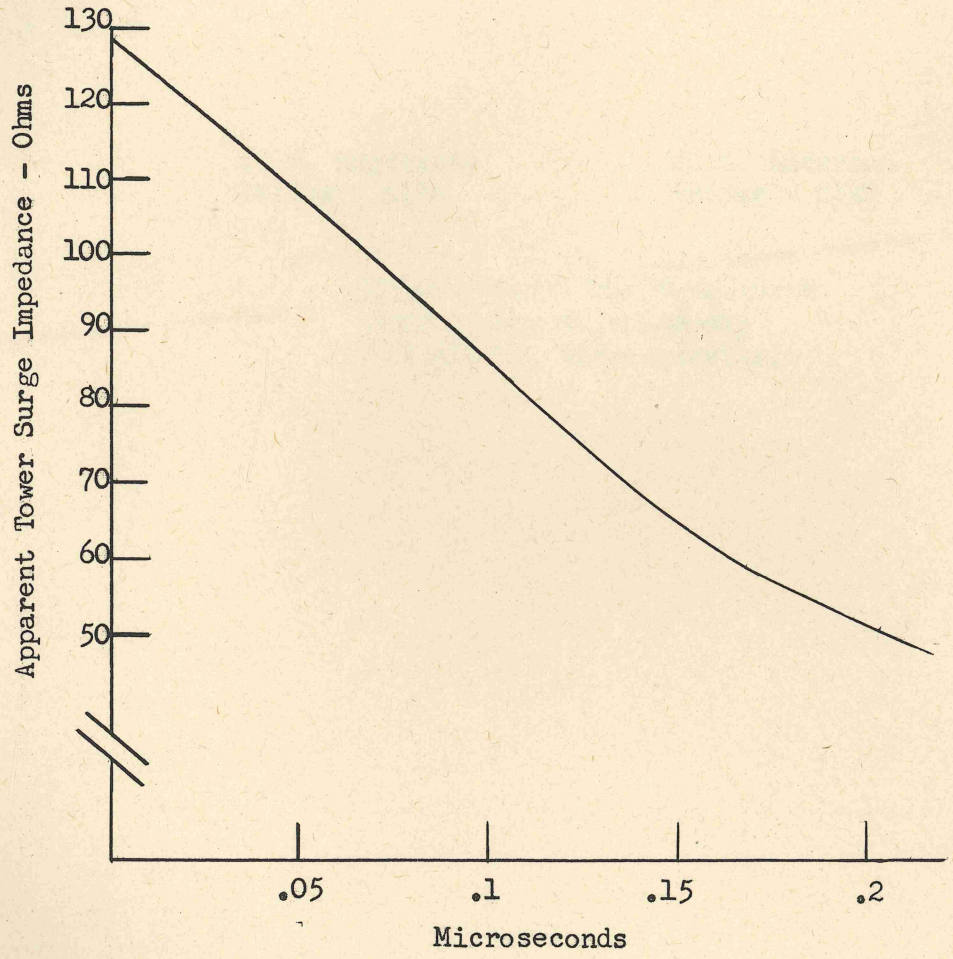

Fig. 9. Apparent Tower Surge Impedance
As A Function of Time
Data From Oscillogram of Fig. 8

FACTORS AFFECTING THE LIGHTNING PERFORMANCE OF TRANSMISSION LINES

J. H. Hagenguth
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INTRODUCTION

In recent years there have been an unexplained large number of outages on the 345 kv OVEC system. In a co-operative investigation several of the factors that may influence the outage rate have been investigated. The principal factors involved in the lightning performance problem are:

Insulation .
Configuration of line.
Frequency of strokes to line.
Frequency of occurrence of current - amplitude
- front time
- rate of rise
Charge distribution in the leader channel and in the ground.
Induced voltage.
Ground resistance.
Coupling effects.

This paper will discuss the charge distribution and resulting induced voltage, as well as a comparison method of calculating lightning performance, and will investigate available statistics to explain the flashover performance.

AN ELECTROSTATIC MODEL OF THE LIGHTNING STROKE PROCESS

It is now believed[1] that the concept of the lightning stroke as a simple generator (injecting a current into the line at the point struck) may be a drastic over-simplification for some lines. The stroke not only injects current into the stricken point, but also induces voltages into lines and towers by the electric and magnetic fields produced around the stroke channel. Calculations of these voltage components have been made by Wagner[1], Szpor[2], and Razevig and Rozenfeld[3], and experimental measurements of the electrostatic components were made by Akopian[4]. In such calculations the channel is generally assumed to be of constant charge density (or constant axial gradient) in order to facilitate solution, and solutions are based on field equation calculations.

However, for complex geometries and charge conditions, the use of the field equations becomes difficult because of the diversity of boundary conditions. A more direct method is the use of models of the lightning process. This is demonstrated in this paper by the use of a geometrical model to determine the currents induced on a phase wire by a direct stroke to an overhead ground wire at mid-span. By this method the buildup of charges on the phase conductors and groundwire by an approaching pilot streamer can be demonstrated, as well as the shielding effects of other conductors or upward streamers from the groundwire. It also permits a study of the buildup of electric fields at the surface of the earth, the measurement of the charges concentrated at various regions of the stroke channel, and an evaluation of phase-conductor induced voltages.

In Fig. 1, a model cloud 12' x 12' was suspended six feet above a conducting ground plane. Since this is a 250:1 model, it represents a cloud 1500 feet above the earth. Greater cloud height could not be obtained because of space limitations, but as long as the cloud is at a considerable distance from the transmission line, it is only the gradients produced near the line that are important, not the actual cloud height.